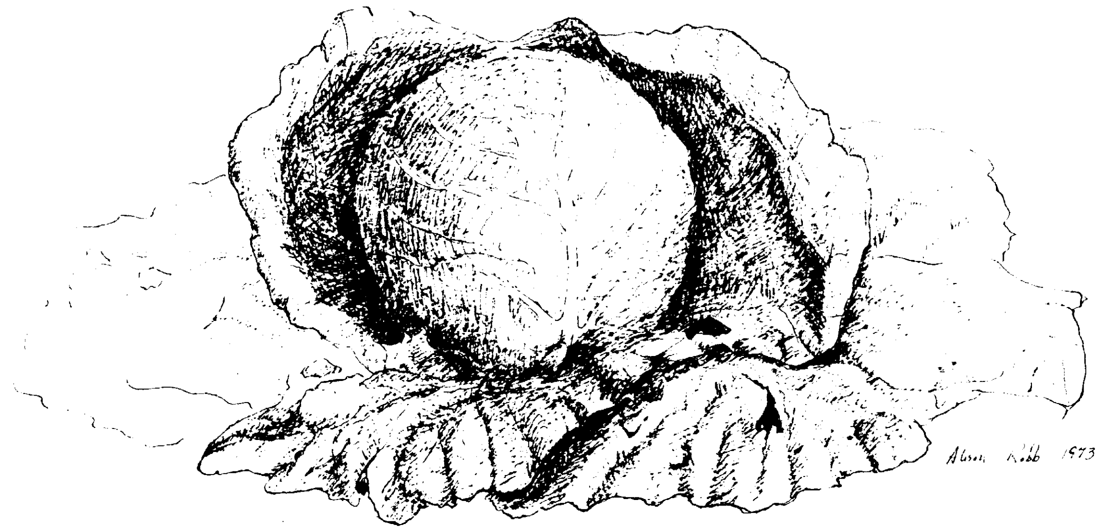
New Alchemy Agricultural Research Report No. 1



A Preliminary Study of Resistance in Twenty Varieties of Cabbages to the Cabbage Worm Butterfly (*Pieris rapae*)

Background to the New Alchemy Agricultural Research

From its inception one of the long range goals of the Institute was to search for food crops including grains, vegetables and fruits that would be best adapted to an agriculture without poisons. We hoped one day to play a part in creating ecologically-inspired agricultures which would emulate nature, restore soils and be productive of nourishing foods.

To date we have had little opportunity to follow our agricultural plans. However, in 1972 and 1973, we organized a small research program to study companion planting and insect resistance in food crops which involved lay collaborators throughout the country working under our guidance. A "do-it-yourself" agricultural research manual was prepared by Richard Merrill and distributed to potential collaborators. We felt that only a widespread search for the best ways to farm or the finest food plants would reveal the answers we sought. The research manual, still available to those of you interested in garden research, allowed collaborators considerable leeway in determining the plants with which they wished to experiment. Unfortunately, when we tried to tally the results, we could form few conclusions, as a given crop or planting combination was rarely duplicated.

The initial failure of the program was our own. Although we had recommended focusing on cabbage varieties in the insect resistance study, we avoided being emphatic on this point, hoping that our fellow collaborators would be so numerous as to provide the sample sizes we needed to analyze the results. This was not the case, and we have learned that the "people as agricultural scientists" program must study initially only one or two quite specific problems and that the research should grow at a slower pace, one determined by our overcoming the pitfalls associated with learning to collaborate with people, often untrained, and situated from one side of the country to the other.

Because of these circumstances, we would like to confine our first agricultural report to our own findings in the New Alchemy East gardens. We carried out a small study to determine if there are any varieties of cabbage that are better adapted to fending off the pests under Cape Cod conditions. We also studied fourteen. varieties of lettuce, but found to our pleasure that all of them avoided serious damage by insects. Lettuce, grown in relatively small plots in close proximity to cabbages, seem to do well in our part of the country without the need for insecticides. Twenty varieties of cabbages comprised the insect resistance experiment reported here.

It is important to point out that I am not an experienced scientist or gardener, so that, in fact, I was playing a role not unlike our fellow collaborators in other parts of the country. I did, however, have access to scientists for tabulation of results and consultation as the study proceeded. I want to emphasize my newness to agricultural research so that others will feel encouraged to do likewise in their own backyards.

The Research Project: A Comparison of Insect Resistance in Twenty Varieties of Cabbages to the Imported Cabbage Butterfly, Pieris rapae

Although we originally planned to study the resistance of the various cabbage varieties to the gamut of cabbage pests in our area, in 1973 there was only one significant insect pest, namely, the imported cabbage butterfly *Pieris rapae*. The larval or caterpillar stages of the cabbage butterfly are notorious for the damage they inflict upon the crucifers including cabbages, collards, Brussels sprouts and broccoli. They are capable of consuming sizeable portions of the leaves and the developing heads of cabbages and other crucifer relatives. The cabbage butterfly worm is a major crop pest and therefore an appropriate subject for study.

There have been relatively few studies of the resistance of cabbage varieties to the cabbage butterfly. A notable exception is the work of Radcliff and Chapman (1965 and 1966) which is treated in a subsequent section.

It is appropriate at the outset to discuss the concept of insect resistance, about which there is so much misunderstanding. The term is frequently interpreted as meaning something precise, and an insect resistant variety of plant is often thought to be one that will not be damaged under any circumstances by a particular insect. But the actuality of the matter is very different and resistance is a relative term. Although resistance has a genetic or inheritable basis, it is often modified by environmental variables including weather, season, soils and so forth. The insect side of the coin is not necessarily stable either, and it is possible that some insects which are highly adaptive may change, and a resistant plant variety may at that point no longer be resistant to insect attack.

The very complexity of insect resistance necessitates definitions. The following are drawn from Reginald Painter's "Insect Resistance in Crop Plants" first published in 1951.

Insect Resistance: Some Definitions

Insect Resistance: Insect resistance is the relative amount of heritable qualities possessed by the plant

Photo by Alan L. Pearlman

which influence the ultimate degree of damage done by the insect. In practical agriculture it represents the ability of a certain variety to produce a larger crop of good quality than do ordinary varieties at the same level of insect population.

Highly Resistant Crop Variety: Is a variety which possesses qualities that result in little damage by a specific insect under a given set of conditions.

Low Level of Resistance: Is a variety that results in less damage or infestation by an insect when compared with non-resistant varieties, but which is not nearly as effective in combating pests under the same condition as a highly resistant variety.

Moderate Resistance: Moderate resistance is intermediate between the above.

Pseudoresistance: The apparent resistance is due to other factors which reduce pest damage and include:

1) Host Evasion: Some varieties evade insect injury by maturing before the pests are present in large numbers. If planted at a later date, they would be susceptible to attack.

2) Induced Resistance: This is resistance due to such factors as soil fertility and not due to genetic or "built in" factors.

3) Escape: Apparently some plants in field trials are known to escape infestation even when pests are present and damaging neighboring plants. Subsequent breeding tests have not indicated in these cases any resistant qualities. The actual cause of the "escape" in this case remains unknown.

Susceptibility: A susceptible variety is one which shows average or more than average damage by an insect.

High Susceptibility: A highly susceptible variety is one with much more than average damage caused by a given insect species.

Methods Used in the Study

NAI's experimental gardens are situated along the northwest edge of a ten-acre meadow which some years earlier was used as pasture for a dairy farm. The land is surrounded by a scrub oak-pine woods typical of many of the sandy soil areas on Cape Cod. The soils are generally acid, low in nutrients and relatively devoid of organic matter. The best soils on the farm are to be found in a depression, which was the area utilized for insect resistance research.

Prior to the experiments the plots were planted to a buckwheat crop which was turned under in the late summer. In the fall a mixed rye and hairy vetch crop was planted and rototilled into the soil the following spring. A layer of compost was applied, and the plots were limed with dolomite limestone before each crop, and again prior to the cabbage experiments.

The experimental area which comprised the study reported here was 85' by 50' and was bordered by marigolds, which were in flower throughout the latter two-thirds of the experiment. Neither adults nor larvae of the cabbage butterflies were observed to be attracted to or markedly influenced by the marigolds, however, the presence of these flowers may have been a factor in the absence of other pests.

Twenty varieties of cabbage (seventeen of the varieties from a single seed company, Twilley) were started indoors in four-hundred pots made of compressed peat (Jiffy Pot Co.) in a mixture of soil, farm compost, and "Earthrite", a biodynamic compost prepared by Zook and Rank Corporation. The upper layer of the pots in which three seeds of a given variety were placed was comprised of vermiculite. On May 20 the seedlings were placed in a coldframe and after the second pair of leaves appeared the two least vigorous plants from each pot were removed. On June 15 the cabbage plants were placed into the experimental garden.

Experimental Design

A randomized planting pattern was used for the study. Other methods (block designs) may be equally suitable and may entail less work in data collecting. For detailed discussion of experimental designs in agricultural research, see NAI's "The Agricultural Research Workbook for 1973: Insect Resistance and Companion Planting in Vegetable Crops" prepared by Richard Merrill.*

Fifteen plants of each of the twenty varieties were placed randomly in the experimental area. Five plants of each variety were held in reserve in the coldframe in case experimental plants were inadvertently damaged. Three hundred positions (equivalent to the number of plants) were delineated in the experimental area in rows 5' apart (running north and south) with 2½' between the positions within a row. Wooden markers were labeled as to variety and number (from one to fifteen) and placed in a box and scrambled. The position of each plant in the experimental area was determined by the drawing of the marker from the box. The cabbage plants were positioned sequentially beginning at one corner of the plot on the basis of the withdrawal of the markers.

Data Collection

During the coldframe period the following information was recorded: date of seeding, date and percentage of germination, weather and environmental variables

***The agricultural research workbook is available from NAI, Box 432, Woods Hole, Massachusetts 02543 for $1.00.**

of particular note, and date of setting out.

In the experimental gardens, data was collected eight times from each plant through the period of the study. Included was:

1) Growth Information
   a. set of leaves
   b. time of heading
   c. comparison in size:
      i. head maturity
      ii. marketability
      iii. weight of the plant (at termination of experiment)
2) Condition of the Plant

   Plants were compared on the following scale, based upon insect damage, health of the plant and a number of subjective factors which could be categorized as "appeal" of the plant for eating purposes.
   a. dead
   b. poor
   c. ok
   d. good
   e. excellent
3) Damage
   a. disease
   b. insect species
   c. density of eggs, larvae or adults depending on circumstances
   d. type of damage:
      i. sucking
      ii. chewing
      iii. wilting
   e. the amount of damage
   f. section of plant damaged

On the basis of the above, it was possible to denote the following categories into which the cabbages could be placed at the termination of the experiment.

Plant Categories

1) Marketable: those with
   a. a compact head
   b. minimum head weight of one pound
   c. very little or no damage to edible portion of the plant
2) Non-Marketable Plants:
   a. those that did not head
   b. head too small in size and weight
   c. head burst or split
   d. damaged by insects or diseases
   e. miscellaneous category in which some essential quality for marketability was lacking
3) Dead

Results of the Experiment

Germination rates in the coldframe were good with over ninety-five per cent germination in thirteen

Photo by Alan L. Pearlman

varieties, greater than eighty-five per cent in four and between forty-five and sixty per cent in the remaining three varieties. When the seedlings were first set out a number succumbed and needed replacing. The damage was mainly due to trampling by dogs and transplant errors. The cabbage butterfly worm was not a factor in these early mortalities.

The relationship between marketability of the cabbages and the presence of the larvae of the cabbage butterfly for all varieties considered together is illustrated in Table 1.

If the early mortality, not due to the cabbage worms, is subtracted from the total, the relationship between marketability and presence or absence of the cabbage worm becomes clearer (Table 2). Ninety-seven out of the total of one hundred and fifty-five marketable plants had cabbage worm populations, suggesting that when the data from all varieties is treated together the relationship between pest infestation and marketability is complex. More of the marketable plants had cabbage worms than those that were less marketable.

Table 1

The Relationship Between the Presence or Absence of Larvae of the Cabbage Butterfly and Marketability of the Cabbages. All twenty varieties are Treated Together.

Cabbages	No. of Plants With Cabbage Worms and Their Equivalent Percentages	No. of Plants Without Cabbage Worms and Their Equivalent Percentages	Totals
Marketable	97 = 32.33%	58 = 19.33%	155 = 51.66%
Non-Marketable	33 = 11%	43 = 14.33%	76 = 25.33%
Dead	16 = 5.33%	53 = 7.66%	69 = 23%
Totals	146 = 48.66%	154 = 51.33%	300 = 100%

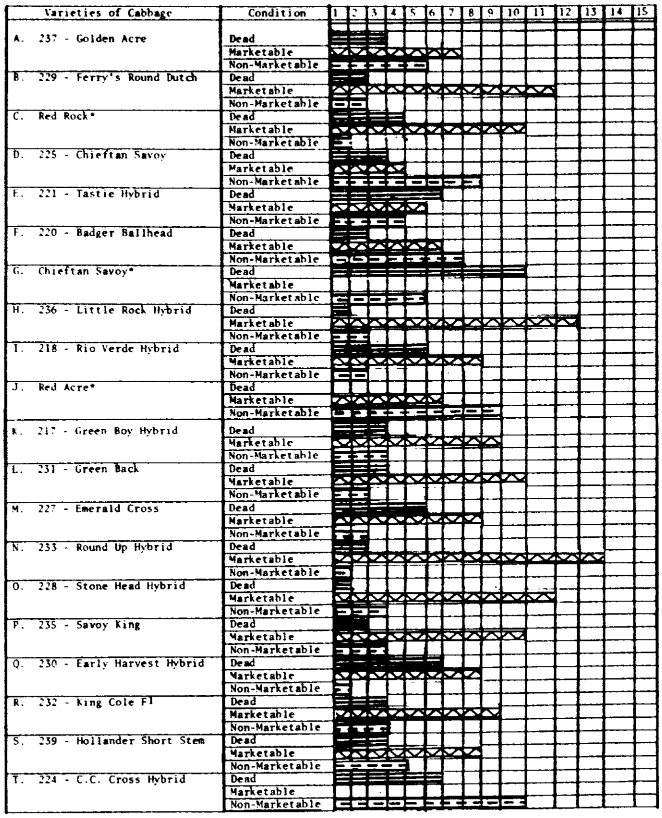
Table 2

The Relationship Between the Presence and Absence of Larvae of the Cabbage Butterfly and Marketability of the Cabbages, After Early Mortality Not Due to Cabbage Worms is Subtracted from the Total. Expressed in Percentages.

Cabbages	Percentage With Worms	Percentage Without Worms	Total
Marketable	42%	25.1%	67.1%
Non-Marketable	14.3%	18.6%	32.9%
Total	56.3%	43.7%	100.0%

Figure 1

A Comparison of the Marketability of Twenty Cabbage Varieties. Seedling Mortalities are Also Shown.



*Letherman Seed Co.
All others Twilley Seed Co.

Dead
Marketable
Non-Marketable

A varietal comparison is presented in Fig. 1. Table 3 gives the varietal comparison coupled to the presence or absence of cabbage butterfly larval infestation. The preliminary evidence suggests that the number of worms and marketability may be related, with more worms on varieties with higher marketability. It should be added at this point that, while the total number of larvae per variety did not exceed twenty-eight individuals over the whole sampling period, an individual cabbage worm is capable, in some instances, of consuming the bulk of a cabbage plant as it matures. In most instances this is not the case as Fig. 1 and Table 3 show.

When the twenty varieties are compared and ranked in terms of marketability, they line up as is shown in Table 4a. Table 4b illustrates in percentages marketability ranking after early mortalities not due to the cabbage butterfly larvae are subtracted from the calculations. Table 4b more accurately reflects marketability ranking when one is considering the impact of the pest on the crop. Round-Up variety had the largest number of marketable plants.

Varieties are ranked in Table 5 according to their yields. Table 5a represents total production per variety, while 5b represents the average weights. Savoy King was the highest yielder, had the highest average weight and housed the largest pest population.

A preliminary ranking of the twenty cabbage varieties most suited to culture without insecticides in our area is denoted in Table 6. A simplified ranking system was employed, summing the ranks from Tables 4 and 5. It should be strongly emphasized, however, that variables unknown to us may have played an important factor in marketability and yield, consequently the following ranking is preliminary. As with all agricultural research, several years of careful experimentation are needed before definitive statements about

Table 3

Cabbage Varieties as Hosts to Larvae of the Cabbage Butterfly: A Comparison Between Marketability and Larval Populations. Larval Numbers Represent the Sum of Eight Larval Counts Per Variety.

Varieties of Cabbage	Marketable Plants Without Worms	Marketable Plants With Worms	1 Number of Worms	Non-Marketable Plants Without Worms	Non-Marketable Plants With Worms	2 Number of Worms	Dead Plants With Worms	3 Number of Worms	Totals of 1, 2 and 3
A. 237-Golden Acre	1	6	8	4	1	1	1	1	10
B. 229-Ferry's Round Dutch	4	7	14	0	2	3	1	1	18
C. Red Rock*	4	6	14	0	1	1	1	1	16
D. 225-Chieftan Savoy	3	1	2	5	3	3	1	1	6
E. 221-Tastie Hybrid	1	4	9	2	2	4	0	0	13
F. 220-Badger Ballhead	3	3	5	4	3	6	1	1	12
G. Chieftan Savoy*	0	0	0	3	2	3	0	0	3
H. 236-Little Rock Hybrid	5	7	15	1	1	1	0	0	16
I. 218-Rio Verde Hybrid	3	5	10	2	0	0	2	3	13
J. Red Acre*	1	5	6	5	4	7	0	0	13
K. 217-Green Boy Hybrid	5	4	8	2	1	1	1	1	10
L. 231-Green Back	6	4	8	1	1	1	0	0	9
M. 227-Emerald Cross	6	2	2	2	0	0	2	2	4
N. 233-Round Up Hybrid	7	6	10	1	0	0	0	0	10
O. 228-Stone Head Hybrid	5	6	11	2	1	2	1	1	14
P. 235-Savoy King	2	8	21	0	3	5	2	2	28
Q. 230-Early Harvest Hybrid	0	8	16	1	0	0	1	1	17
R. 232-King Cole F1	2	7	18	1	2	3	1	1	22
S. 239-Hollander Short Stem	0	8	16	2	2	2	0	0	18
T. 224-C.C. Cross Hybrid	0	0	0	5	4	5	1	1	6
Totals	58	97	192	43	33	48	16	17	257
	155			76					

*Letherman Seed Co.
All others Twilley Seed Co.

Table 4

Marketability Rankings

Table 4a

Cabbage Varieties Ranked as to Number of Marketable Plants (Maximum Possible = 15)

Variety	Number of Marketable Plants 15P/Variety	Worm Count
Round Up Hybrid	13	10
Little Rock Hybrid	12	16
Ferry's Round Dutch	11	18
Stone Head Hybrid	11	14
Savoy King	10	23
Red Rock*	10	16
Green Back	10	9
King Cole F[1]	9	22
Green Boy Hybrid	9	10
Hollander Short Stem	8	18
Early Harvest Hybrid	8	17
Rio Verde Hybrid	8	13
Emerald Cross	8	4
Golden Acre	7	10
Badger Ballhead	6	13
Red Acre*	6	13
Tastie Hybrid	5	13
Chieftan Savoy	4	6
C.C. Cross Hybrid	0	6
Chieftan Savoy*	0	3

*Letherman Seed Co.
All others Twilley Seed Company

Table 4b

Cabbage Varieties Ranked as to Percentage of Marketable Plants Minus Those Which Died Prior to Cabbage Butterfly Larvae Infestation

Variety	Percentage of Marketable Plants Minus Dead	Worm Count
Round Up Hybrid	92%	10
Red Rock*	90%	16
Early Harvest Hybrid	88%	17
Little Rock Hybrid	85%	16
Ferry's Round Dutch	84%	18
Green Back	83%	9
Emerald Cross	80%	4
Rio Verde Hybrid	80%	13
Stone Head Hybrid	78%	14
Savoy King	76%	28
King Cole F[1]	75%	22
Green Boy Hybrid	75%	10
Hollander Short Stem	66%	18
Badger Ballhead	60%	13
Golden Acre	58%	10
Tastie Hybrid	55%	13
Red Acre *	40%	13
Chieftan Savoy	33%	6
C.C. Cross Hybrid	0%	6
Chieftan Savoy*	0%	3

*Letherman Seed Co.
All others Twilley Seed Company

Table 5

Yield Rankings

Table 5a

Cabbage Varieties Ranked as to Weight of Marketable Plants

Variety	Total Marketable Weight lbs	oz	Worm Count
Savoy King	42	10	28
Round Up Hybrid	37	4	10
Little Rock Hybrid	30	14	16
Red Rock*	29	11	16
King Cole F[1]	27	4	9
Green Boy Hybrid	26	15	10
Ferry's Round Dutch	26	5	18
Rio Verde Hybrid	25	7	13
Stone Head Hybrid	20	10	14
Green Back	19	5	9
Hollander Short Stem	16	--	18
Golden Acre	15	15	10
Early Harvest Hybrid	15	12	17
Chieftan Savoy	11	--	6
Emerald Cross	10	2	4
Tastie Hybrid	8	14	13
Badger Ballhead	6	11	13
Red Acre*	4	14	13
C.C. Cross Hybrid		0	6
Chieftan Savoy*		0	3

*Letherman Seed Co.
All others Twilley Seed Company

Table 5b

Cabbage Varieties Ranked as to Average Weight of Marketable Plants

Variety	Average Marketable Weight lbs	oz	Worm Count
Savoy King	4	4	28
Red Rock*	3	11	16
Rio Verde Hybrid	3	10	13
Green Boy Hybrid	3	8	10
King Cole F[1]	3	--	22
Golden Acre	2	14	10
Round Up Hybrid	2	13	10
Chieftan Savoy	2	12	6
Little Rock Hybrid	2	3	16
Ferry's Round Dutch	2	6	18
Hollander Short Stem	2	--	18
Early Harvest Hybrid	1	15	17
Stone Head Hybrid	1	14	14
Green Back	1	14	9
Tastie Hybrid	1	12	13
Emerald Cross	1	4	4
Badger Ballhead	1	1	13
Red Acre*		13	13
C.C. Cross Hybrid		0	6
Chieftan Savoy*		0	3

*Letherman Seed Co.
All others Twilley Seed Company

Table 6
Preliminary Ranking of Cabbage Varieties Exposed to Cabbage Butterfly Larval Infestations. The Four Ranks from Tables 4 and 5 are Summed. Best Performers at the Top of the Scale.

C A B B A G E V A R I E T I E S					
Best		Intermediate		Poor	
Round Up		Ferry's Round Dutch		Chieftan Savoy	
Red Rock*		King Cole F^1		Badger Ballhead	
Savoy King	Identical Rank	Rio Verde Hybrid	Identical Rank	Tastie Hybrid	
Little Rock Hybrid		Green Boy Hybrid		Red Acre*	
		Stone Head Hybrid		C.C. Cross Hybrid	Identical Rank
		Green Back		Chieftan Savoy*	
		Early Harvest Hybrid			
		Hollander Short Stem			
		Emerald Cross			

*Letherman Seed Co. All others Twilley Seed Co.

relative resistance can be made. We can say, however, that the best varieties listed in Table 6 performed well in our 1973 field trials.

I was interested in determining from the first year's results the biological relationships between the larvae of the cabbage butterfly and the marketability and yields of cabbages. Three correlations were tested for significance by the Spearman rank test (Siegel, 1956). The correlation between worm density and the number of marketable plants was suggestive ($P < 0.1$). Worm density was significantly correlated with percentage of marketable plants and with average marketable weight ($P < .05$ in both cases). It would appear that the larvae of the cabbage butterfly have a tendency to prefer the higher yielding and more marketable varieties we studied. This strongly suggests that cabbage butterfly resistance in cabbages is not some factor which causes the butterfly to avoid a resistant variety. The contrary seems true. Resistance seems to involve some ability on the part of the plant to head, mature and avoid destruction in the presence of feeding larvae.

Discussion

Radcliffe and Chapman (1965 and 1966) studied the resistance of sixteen varieties of cabbages to the worm of the cabbage butterfly. The study was carried out in Kenosha, Wisconsin, over a two-year period. The first year they used ten plants per variety and the second year fifteen. A complete comparison of the two studies is not possible for at least two reasons; firstly, only two varieties, Red Acre and Hollander, were common to the two studies; and secondly, Radcliffe and Chapman provided no yield or marketability information on the varieties they studied, despite Painter's (1951) definition of resistance as:

> "The ability of a certain variety to produce a larger crop of good quality than do ordinary varieties at the same level of insect population."

Instead Radcliffe and Chapman determined resistance exclusively on the basis of density of pest infestations, determining relative resistance by the numbers of cabbage worm larvae on a given variety. The varieties with the least numbers of worms were scored as the most resistant. Determined this way their findings are misleading, especially to practicing farmers who need resistance information based on yields and marketability. Radcliffe and Chapman ranked the Red Acre variety as one of the most resistant to the cabbage worm larvae, as it had a low infestation of worms. I also found that Red Acre had a relatively low worm count but ranked it as a poor variety because only forty per cent of the Red Acre plants were marketable and the yields were very poor, less than one-eighth that of the best yielding variety. Both studies showed that there were fewer pests on the Red Acre variety, but my work indicates that the few pests that were present were enough to affect severely production and marketability.

Acknowledgments

I should like to thank those who helped me with the study. Prof. E. O. Wilson at Harvard University and Prof. Richard Root at Cornell University introduced us to the literature on cabbages and their insect associations.

Dr. Woolcott Smith and Ms. Mary Power of the Woods Hole Oceanographic Institution assisted in interpreting the data and the statistical analysis.

Ms. Cynthia Knapp provided invaluable guidance on the preparation of the tables and figures.

Last, but not least, I should like to thank all the Alchies who helped me plant, transplant and count bugs.

- Hilde Atema

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A Brief Natural History of the Imported Cabbage Butterfly, *Pieris rapae*

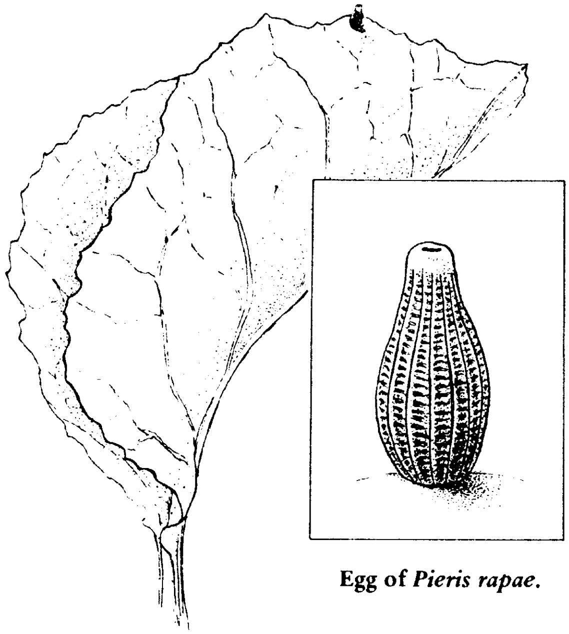
On a particularly warm day at the end of April, the first cabbage butterflies appear on New Alchemy's Cape Cod farm. In the spring sun they hover and flutter over patches of early winter cress, *Barbarea verna,* the first crucifer or mustard plant to flower in our area. The winter cress is an early season host for this notorious butterfly whose larvae are despised as a major pest of cultivated cabbages and their relatives. From spring to the first frosts, this black-dotted, white butterfly is very much with us and, while their larvae can and do damage our crops, we would be unhappy if this beautiful creature were to become absent from our gardens. They are a dance.... light and movement... and our insect resistance research is a way for us to accommodate ourselves to their presence.

The following is a brief description of the natural history of the imported cabbage butterfly, *Pieris rapae.* It is presented because we believe that stewardship must be preceded by learning as much as one can about the living world which sustains us. Most of the information comes from Richard's paper "The Biology of the Small White Butterfly" and Harcourt's "Biology of Cabbage Caterpillars in Eastern Ontario." These are supplemented by my own observations. The biology of this butterfly as given here is only an introduction; those who wish to glean more of the subtle relations between cabbage butterfly and the plants which influence them would do well to read Richard Root's outstanding, if somewhat awkwardly-titled, paper, "Organization of a Plant – Arthropod Association in Simple and Diverse Habitats: The Fauna of Collards (*Brassica oleracea*)" as well as other related scientific papers. The papers are not too difficult for the uninitiated, armed with an insect field guide and an elementary ecology text, to understand. You will discover within Root's ecological studies of food plants and their insects the first patterns of an adaptive agriculture.

Pieris rapae, the imported cabbage butterfly, originated in Eurasia and has appeared only within recent times in North America. The first known specimen was captured in 1860 by William Couper of Quebec. The species spread rapidly; within three years, it had become a serious pest within a forty-mile radius of Quebec city and by 1886 had reached as far as the Gulf of Mexico in the south, Hudson's Bay in the north and the valleys of the Rocky Mountains in the west.

The life cycle of the imported cabbage butterfly involves a complete metamorphosis through four stages: egg; caterpillar with five instars or molts; pupa; and butterfly or adult. In climates comparable to New England there are, on the average, four generations a year, with the last generation overwintering as dormant pupae. The pupae which overwinter emerge as adults during the month of May.

Pierid butterflies are good flyers. Migrations of *Pieris rapae* have been documented. It has been suggested that, at the beginning of a season, the adults present are those which have emerged from pupae within the immediate area, but, as the season proceeds, recruits are drawn in from outside. Late summer populations may include individuals who have migrated considerable distances.



Egg of *Pieris rapae.*

Egg

Pieris rapae eggs are attached by their bases to the underside of crucifer leaves. They are flask-shaped, about 1 mm long and 0.5 mm in diameter, and pale when first laid. Just before hatching they are a straw-yellow color. The female lays the eggs singly before moving on to another site. The number of eggs laid varies considerably. Estimates range from less than twenty to more than four hundred per female. Richard was not able to find any correlation between the abundance of eggs and the number of larvae or caterpillars.

The speed at which the egg hatches is temperature-dependent. Under laboratory conditions they have been shown to hatch in as little as two days at 32°C but may take as long as twenty-seven days at 7°C. During the summer the average egg hatches during a four to eight day period. Eggs are found on most members of the cabbage or crucifer family, but preferences between family members range widely. Cabbage, turnips, mustard, horseradish, bitter cress, broccoli, cauliflower and nasturtiums are common hosts, while shepherd's purse and wallflowers, amongst the crucifers, are avoided. Eggs are laid on sea kale, *Crambe maritima,* but apparently the larvae are unable to survive on a sea kale diet.

Larvae

The larvae or caterpillars are cylindrical in shape. Their head and body are pale green with a lemon-colored stripe over the middle of the back. They blend exquisitely with the foliage of most crucifers and it takes a practiced eye to detect their presence. Often their location can be spotted by the presence of their greenish excrement or droppings.

As soon as the larvae emerge they begin feeding, remaining on the outer leaves of the plants during the first two instars (an instar is an intermolt period). During the third instar the larvae move inward towards the more central region of the plants. In the final two instars the caterpillars feed voraciously, gnawing big holes in the leaves and edible portions of plants such as the heads of cabbages. At this point their presence is readily detected by the mounds of droppings; however, in some instances they burrow so far into the head that their presence is almost impossible to detect, short of removing the head and cutting it open.

The first four instars pass in a brief period of between two and five days. The final instar may last up to fourteen days and, during this period, larvae may grow from 3.2 mm to 30 mm. A caterpillar will live for between 11 and 30 days before pupating. The lifespan is dependent upon food resources, while the climate remains the ultimate regulator of the life cycle.

Larvae have been known to migrate from their food plant to another plant upon which to pupate. This makes good sense for a food crop pest as it is adaptive for the population to have an alternative host. Crops are usually removed for transport to market and, if the pest population was removed with the crop each time, it would fall into hard times.

We have been unable to learn if larvae migrate from food plant to food plant in search of the tastiest variety. I observed that larvae, when removed from their host plant, were capable of returning over a short distance to the original plant; but I have no idea if they use this talent to move on to better

Young cabbage plant with caterpillar (*Pieris rapae*) feeding grounds. Larvae normally stay on the plant where they hatch until it is time to pupate, but it would be interesting to determine how fixed this behavior is. I can think of one possible instance when only one stage of larval migration might be of value. Red cabbage are not as attractive as green ones to the female butterfly; however, it has been determined that larval survival rates are higher on red cabbage, perhaps because of its higher nutrient levels which include vitamin C. It might make sense for a larva to migrate to red cabbages under certain circumstances. However, the low worm counts on our red varieties tend to support the traditional notion that larvae stay put until it is time to pupate.

The number of larvae depend upon many factors, including nutritional value and palatability of the food plant as well as its condition. The weather also has a profound influence and, during heavy rains, it has been found that the larvae often perish by drowning.

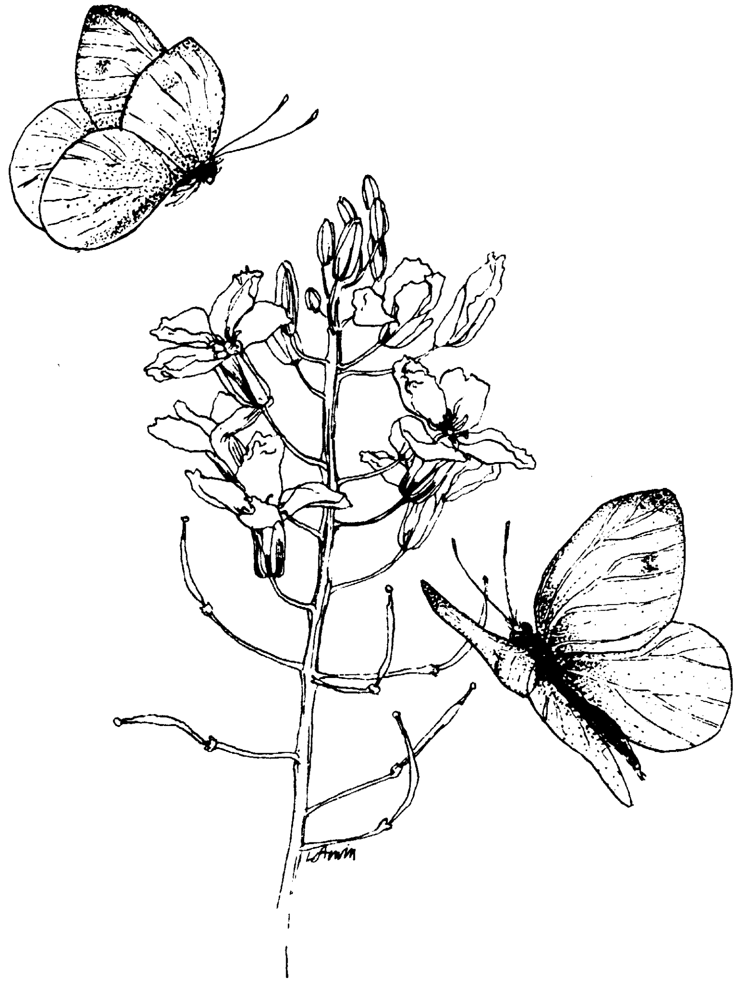
The worms of the cabbage butterfly do not suffer a large degree of predation due to their toxic body fluids. Birds, chiefly brown-headed cowbirds, song sparrows and redwing blackbirds, are known to eat cabbage worms, but to what extent has yet to be determined. Spiders may prey on the larvae, especially along the edge of cultivated areas where there are suitable spider habitats.

The larvae are parasitized by at least six species of insects with the most important cause of death, due to parasites, being caused by the braconid wasp, *Apanateles goleratus*. The female braconids lay their eggs in the first two larval instars of the cabbage worm and the parasitic larvae feed upon their insides. The satiated parasitic predators remain until the hosts spin their pupal mat. In most instances, the life cycle of the cabbage butterfly is interrupted at this point.

The caterpillars of the cabbage butterfly are killed in large numbers by a highly virulent granulosis disease and, in southern Ontario, mortalities due to the virus have ranged as high as ninety-four per cent. The presence of the disease can be spotted by the occurrence of dead and blackened larvae. The contents of their bodies ooze out over the leaves.

Pupae

The pupal stage of the cabbage butterfly is passed as a chrysalis, or naked pupa, which is attached to a spun cushion by hooklets. The head is beaked in front and the pupae measures 18 mm in length. Chrysalis blend subtly with their environment and range in color from pale green to speckled brown. They can be found on fence posts, outbuildings and stumps, as well as on a variety of host plants. It is difficult to determine the pupal densities because of this propensity to locate upon a diversity of plants and objects. *Pieris rapae* overwinter as pupae.



Cabbage butterflies around kale flowers in early season.

Butterfly

The male cabbage butterfly is white with a black spot in the middle of each forewing and a less prominent spot on each of the hindwings. The female is slightly larger than the male and is a creamy-white to yellow-buff color. There are two black spots on the forewings and one black spot on the hindwing.

Within twenty-four hours of emergence from the chrysalis, mating begins and is very soon followed by oviposition or egg laying. While in copula the female sits passively with her wings closed on the host plant waiting for a male. The males flutter from plant to plant and are attracted to the females by visual signals. Sexual odors or pheromones may also play a role in the mating behavior.

A female, over her approximately three-week life span, can lay up to four hundred eggs. Most are laid singly or on occasion in pairs. Egg laying is a fascinating act. The females hold on to the edge of the leaf and bend their abdomens around so that they can deposit their eggs on the underside of the leaf. After an egg is laid, she will fly and feed upon the nectar of flowers and the honeydew of aphids before repeating the process.

Courtship behavior occurs throughout the day during the warm summer months. Cabbage butterflies start flying about two hours after sunrise and their activity peaks at about noon. High temperatures and low wind velocities provide the optimal conditions for mating and on cold, rainy and windy days courtship slows or ceases.

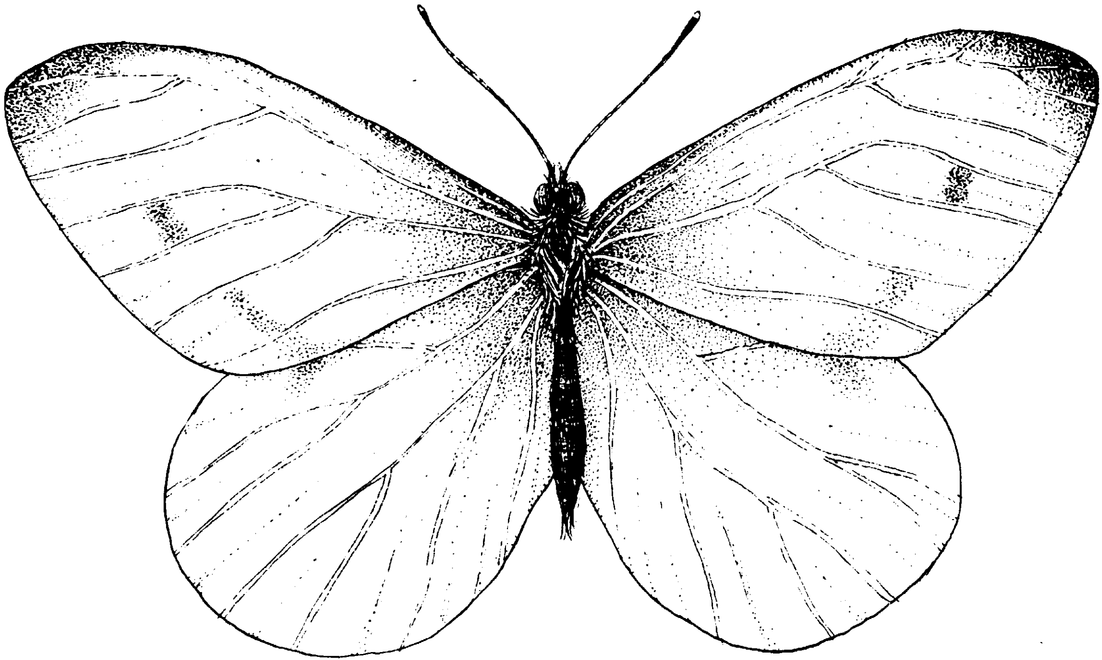
Our studies and observations upon the cabbage butterfly have helped to guide us in trying to learn a little about an agriculture which works in tune with nature. As we discover the delicate machinations of an insect and its host, we begin to admire the whole, and we are inspired to look for modes of growing foods within an ecological framework.

In our gardens, we should be growing those varieties that the cabbage butterflies survive upon, without destroying, or we should grow sea kale which the butterflies do not like. At the same time, we should let the wild crucifers flourish, so that we will be assured that the little white butterfly, with dots on the wings, will remain with us.

How then can the harvest fail?

—*Hilde Atema*

— Artist: *Leslie Arwin*



Adult of the *Pieris rapae*.

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