A SELF-PROPELLED MACHINE FOR MASS COLLECTION OF INSECTS

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY
DAVID L. COBB
1974

ABSTRACT

A SELF-PROPELLED MACHINE FOR MASS COLLECTION OF INSECTS

By

David L. Cobb

A self-propelled machine for the mass collection of insects was developed. The machine operates by a vacuum from a fan drawing insects at high velocity through a narrow opening into a net in a wide chamber where air velocity is low. The fan and collector are mounted on a frame that is propelled by a 9 hp engine at speeds up to 3.4 mph. The device is reasonably low in cost (about $1300), easily transported, and relatively trouble-free in operation. It is small enough that it causes a minimum damage to crops where used.

The machine was designed primarily to collect adults of the cereal leaf beetle, Oulema melanopus (L.). Its range of effectiveness was tested using the insect complex of alfalfa. The machine can collect from about 6.26 acres during a normal work day; an estimated 2.44 acres/day can be sampled with a sweep net. The per acre costs of operation and labor with the machine ($7.10) are nearly as high as the labor costs with sweep nets ($8.85). The effectiveness in collection with the machine varies with the species.

The machine was less effective with the medium to large sized active insects than with other types. The machine collected an average of 3.77-fold the number of insects per area collected as did the sweep net. The per-insect cost with the machine is appreciably less than with the sweep net. The machine can also be used under conditions that would hamper the use of sweep nets.

The machine proved easily adaptable to a wide range of collecting conditions. With modification, the machine should meet the needs for a small, easily transported mass collecting device for many entomological studies.

A SELF-PROPELLED MACHINE FOR MASS

COLLECTION OF INSECTS

By

David L. ee Cobb

A THESIS

Submitted to

Michigan State University

in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

Department of Entomology

1974

6 58011

ACKNOWLEDGEMENTS

The author expresses his gratitude for the assistance received from others in every phase of this work. My advisor, Dr. R. F. Ruppel, advised and assisted in many ways. Dr. W. G. Bickert, D. F. Kampe, L. R. Pickett, D. E. Wolfe, and W. Bushaw were most helpful in the design of the device that was developed. Drs. F. W. Stehr and D. L. Haynes, and Messrs. D. C. Kaiser and M. D. Montei of Michigan State University assisted in the field testing, and the latter two in the tedious sorting and counting of the insects required in the tests. The author's colleagues in the USDA encouraged and assisted the work in many ways: Drs. J. A. Webster, D. H. Smith, Jr., and Messrs. R. V. Connin, R. J. Wolthuis, B. Doyle, W. Johnson, R. Brandt, H. Sherman, J. Vallender, and P. Engstrom.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Field collection of large numbers of insects is a common need in insect studies. Such field collecting is usually done by sweep nets. Sweep nets have been used for mass collections of adults of the cereal leaf beetle, *Oulema melanopus* (L.), for a research program on this pest by USDA personnel at Michigan State University. The use of the sweep net requires high labor inputs. A mass collection device that would lower the need for labor was desirable, and a mass collection device was designed to fulfill this need.

Large numbers of a variety of other insects are also sporadically required at Michigan State University. Two recent examples are: parasitized adult alfalfa weevil, *Hypera postica* (Gyllenhal), for a biological control project; and tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), for plant damage studies. The time that the mass collection machine is needed for collection of the cereal leaf beetle is limited. The machine could be used for the collection of other insects. The effectiveness of the machine in collecting a range of insects was, therefore, made a part of the present study.

The general specifications for the mass collection machine were drawn up with its specific use at Michigan State University in mind. The specifications were: a) intermittant use that necessitated a reasonably low cost; b) use wherever the insects were abundant that necessitated ease of transport; c) frequent use in crops of private farmers that required a minimum damage to the crop; d) use in a variety of collecting situations (viz. stubble, headed grains, and heavy grasses, for cereal leaf beetle collection) that required easy adaptability of the device; e) a minimum need for labor that necessitated ease of operations; f) use in rural areas that necessitated trouble-free operation and the use of standard parts; g) and, most importantly, an effectiveness at least equal to the sweep net.

A mass collection machine that met these specifications was developed and is described below. The design is not considered final, and undoubtedly will be altered for special purposes. Alterations proved easily made during development of the present model. The machine should be readily adapted to the special needs of many entomologists.

DESIGN AND CONSTRUCTION

Literature on mass collection devices for insects is extremely scarce and use was made of literature on insect sampling and control equipment in designing the present machine. Riley *et al.* (1876) presented a number of mechanical devices for destruction of grasshoppers. While man or horse-powered, some of the basic designs were sound for mass collecting. The present machine is, essentially, an adaptation of the J. A. King vacuum collector described in this old article.

Development of vacuum-type mass collection devices apparently stopped for a long time, and the use of a vacuum was developed for insect sampling. A laboratory vacuum aspirator for separation of insects from field samples was developed by Hills (1933). Johnson *et al.* (1955) adapted a vacuum motor that could be used to separate insects from samples in the field. Dietrick *et al.* (1959) developed a portable, gas-powered vacuum device that drew the insects directly into a net for sampling. This device was later adapted with a small gas motor that could be carried on a man's back for sampling (Dietrick 1961). This last model is available commercially and is widely used for sampling insects (*viz.* Stern 1960, Maki 1965). A wheeled cart adaptation of this device was developed by Schroder (1970).

The first use of a portable mass collection vacuum device was reported by van den Bosch *et al*. (1959) for mass collection of parasites of the spotted alfalfa aphid, *Therioaphis maculata* (Buckton). This was a truck-mounted fan connected by ducts to a scoop on the front of the truck. Insects hit the scoop, were drawn into the ducts, and the debris roughly sorted by a coarse mesh nylon net while the insects passed through to a finer organdy net. They report that this device could cover 30 to 40 acres per day and collect millions of parasites under favorable conditions. Stern *et al*. (1965) mounted the same type of device on a high clearance tractor and used it for mass collection of *Lygus hesperus* Knight. The Stern machine used funnels containing three grades of screening to partially sort the insects from the debris and used forward-facing funnels in place of the scoops used on the van den Bosch device. They report that a total of 80 man-hours were used with the device to collect about 3 million *L. hesperus* and note that this represents a considerable saving over cost of rearing this number of insects.

A machine using an air blast to blow insects into containers was developed for insect control in cotton (Parencia 1968). Its use for this purpose was not satisfactory, but it showed potential for the detection and sampling of some insects (Parencia *op. cit*.). Kirk and Bottrell (1969) combined this air blast principle with heated air in a device for sampling low populations of boll weevil, *Anthonomus grandis* Boheman, in cotton. The air speed (up to 135 mph) required for these machines make their use for collecting living insects doubtful.

DESIGN

The first attempt to make a mass collection device for this study was a self-propelled frame with two, horizontally rotating sweep nets mounted on the front (Figure 1). The theory was sound, but the operation of the device proved poor for several reasons: it could not be used in low vegetation without threat of damage to the nets; rotation of the nets proved erratic because of resistance in heavy vegetation; the nets tended to tear or roll up on their frames in use; mechanical problems were frequent; and most importantly, adjustments of the height of the nets and their rotational speed proved very delicate. A better designed mechanical collector, perhaps similar to the Gould tumbler device described in Riley *et al*. (*op*. *cit*.), may have overcome the problems encountered with the net design. The development of the mechanical collector was dropped, as the use of the vacuum system appeared to offer greater promise in overcoming the problems.

The primary advantages of the vacuum-type collector over a mechanical device were the reduction of damage to the insects during collection and the elimination of moving

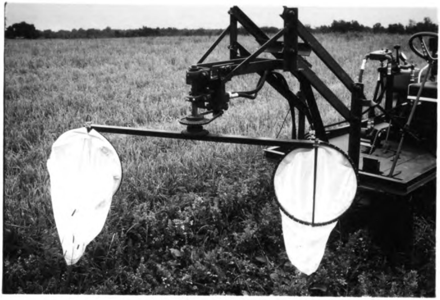

Figure 1. Hydraulic powered rotary sweep nets that were tested as a mass collection machine.

parts exposed to damage. The machine was intended primarily to collect cereal leaf beetle adults, a medium-sized species that tends to drop when disturbed (Castro _et al_. 1965). The machine had to be able to actively pick up such insects as well as trap them as they flew. The funnel collectors used by Stern _et al_. (_op_. _cit_.) did not appear to be suitable for this. The device would also be used to collect cereal leaf beetles close to the ground in stubble or young grain. A scoop system, such as used by van den Bosch _et al_. (_op_. _cit_.) required clearance to avoid damage to the scoop.

A vacuum head set as low as possible with high air movement to draw even inert insects into the collector was needed. Preliminary laboratory trials were made of a narrow slit opening on the high vacuum fan described below. The trials were made by hand pushing a piece of plywood containing 50 gm samples of oat seed under a narrow opening while the fan was operated at varying speeds. The oat seeds averaged 29 mgm (about four times the average weight of a cereal leaf beetle adult reported by Castro _et al_. (_op_. _cit_.)). The collector drew in increasing amounts of seed with increased fan speeds of from 2255 to 3720 rpm (Figure 2). The amount of seed drawn in decreased at fan speeds above 3720 rpm. The fan speed of 3720 rpm requires an engine speed of 2750 rpm; this engine speed was used as a standard governor speed for the engine of the device. The oat seed was not drawn into the collector when placed

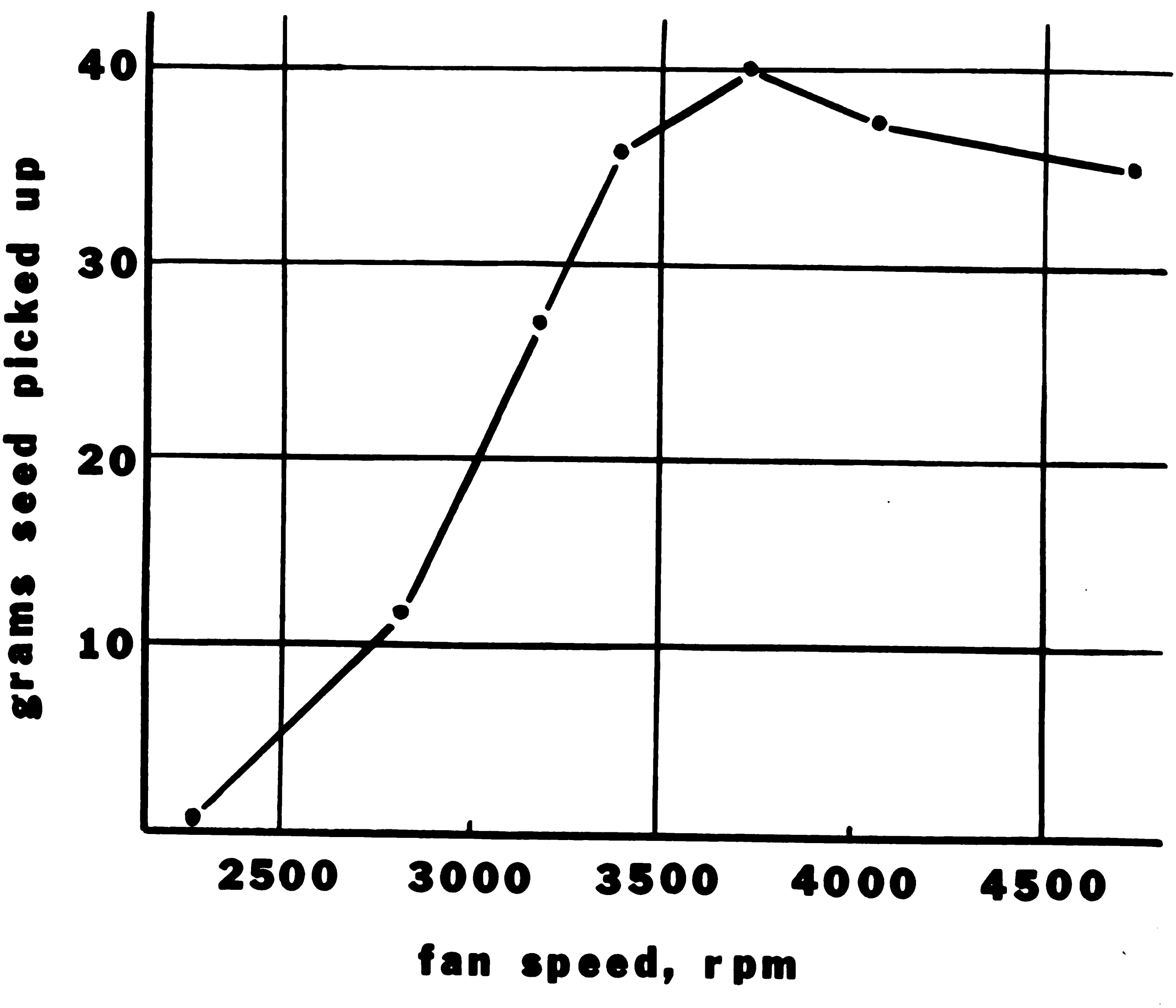

Figure 2. Grams of oat seed picked up by the vacuum mass collection machine at different fan speeds.

on a 16-mesh screen instead of the solid plywood, indicating that air swirling from the sides as well as from below is needed to lift objects into the collector. The vacuum head design fitted the needs for collection of cereal leaf beetle, and further development of the mass collection device was based on this principle.

The air speed at the opening was high and could damage insects. The air speed was lowered by enlarging the area where the insects were trapped in the net (Figure 3). Measurements were made of the air flow at the opening and at the fan exhaust at different engine speeds. The measurements also showed a drop-off in the increment of air speed at the opening as engine speeds exceeded 2750 rpm even though air velocities at the fan exhaust continued to increase with increased engine speed (Figure 4). The drop in air speed at the opening was caused by increased static pressure. Estimates of air speed, based on the air intake at the opening when the engine was operated at 2750 rpm, showed that the insects enter the opening at about 36 mph, go through the collector inlet at about 22 mph, and are held in the collector by a wind of only 10 mph.

THE FRAME AND DRIVE TRAIN

The frame of the device is a 42-in. by 75-in. rectangle of 3-in. channel iron (Figure 5). Wheel supports were placed beneath this frame to allow for a 16-in. clearance of the plants; 3.00 x 16.00 in. motorcycle wheels were used in

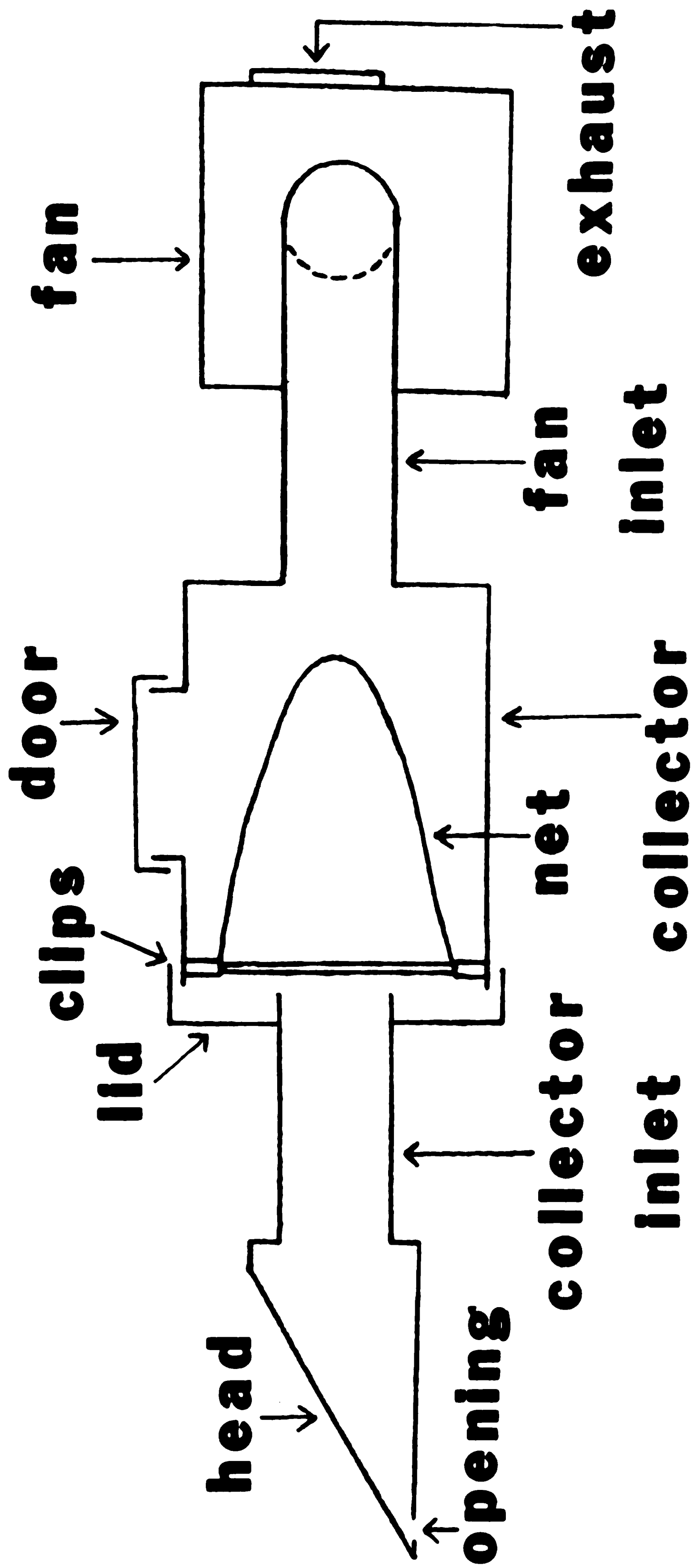

Figure 3. Diagram of the vacuum mass collection machine.

air speed, mph

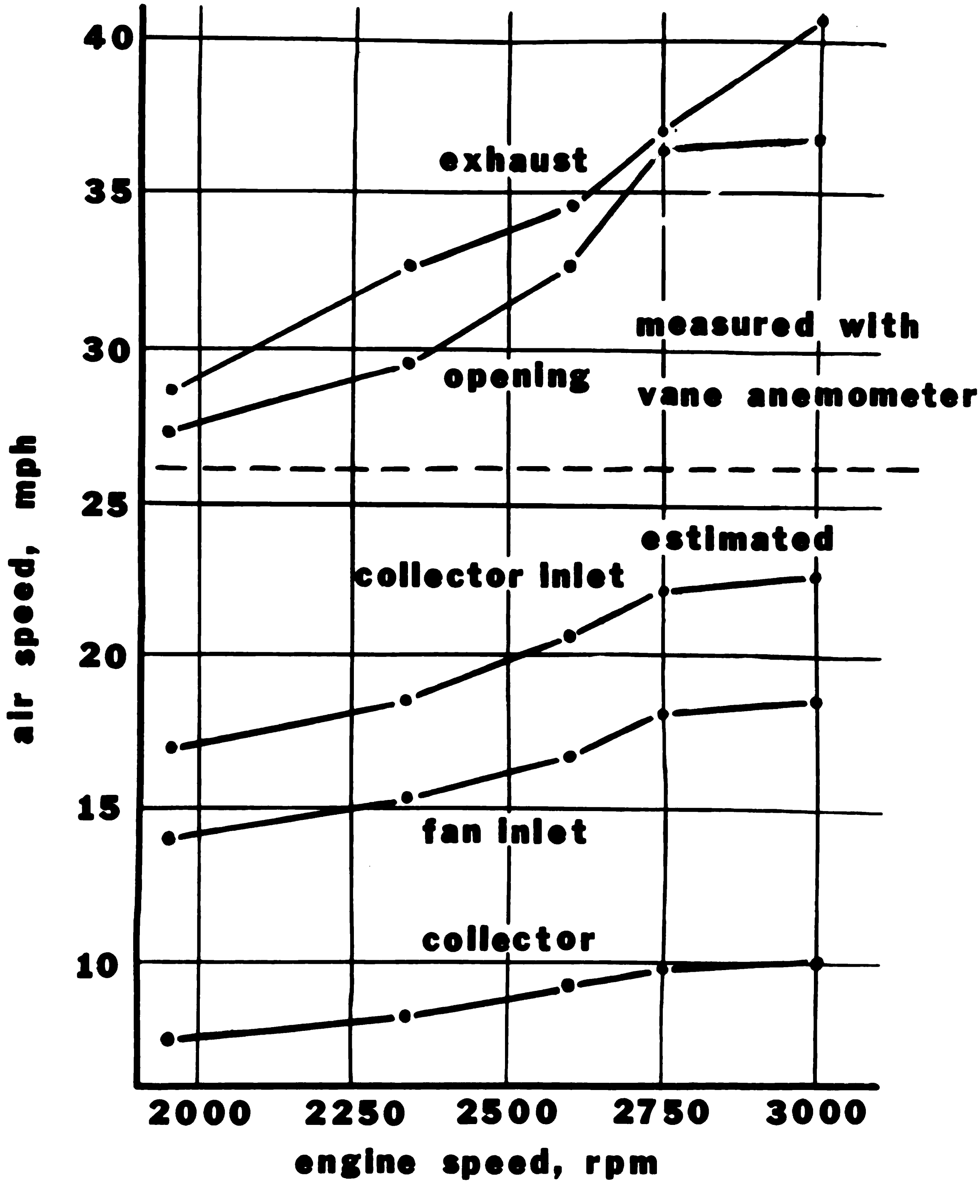

Figure 4. Air speeds at different points of the mass collection machine operated at different engine speeds. (The increase in air speed at the exhaust at 3000 rpm engine speed probably caused by air leakage throughout the system.)

Figure 5. General view of the vacuum mass collection machine.

back and two similar wheels complete with brake assemblies were used in front. The back wheels were mounted in forks of 2-in. channel iron. A steering wheel operated through an automobile steering gear was connected to the back wheels. Individual foot-operated brakes were installed. A seat and operator controls were mounted over the drive wheels. V-shaped iron rod dividers were placed in front of each wheel to avoid damage to the crop. The wheel base was set at 28-in. so that the wheels could be centered between 7-in. grain rows.

The power source was a 9 hp 4-cycle engine mounted on the frame with rubber mounts. The engine was connected to a hydraulic gear pump-tank combination unit by two V-belts. The pump moved hydraulic fluid through a directional control valve (forward or reverse) and then through a variable flow divider valve (speed control) to either a 9 hp hydraulic orbital motor or back to the supply tank. The return oil from the hydraulic motor was passed through a black iron pipe radiator and a filter on return to the supply tank. The hydraulic motor was connected to a 3-speed garden tractor transaxle by a roller chain. The transaxle was connected to the front power wheels by drive chains.

The forward speed of the device could be controlled by engine speed, the variable flow divider valve, and by the transaxle. The engine was also used to power the fan (see below) and was generally operated at 2750 rpm to provide the necessary power to both power train and fan. Standardization of forward speed for the field tests was obtained by fully opening the variable flow divider valve and altering speeds by selection of the transaxle gears. The speeds attained by the machine were: 1.4 mph in first gear; 2.0 mph in second gear; and 3.4 mph in third gear.

THE FAN AND COLLECTOR

A 12-in. diam. non-overloading, flat blade, backward inclined blower rated at 2895 cfm at 2610 rpm with 1/4-in. static pressure was used as a vacuum source (Figure 5). The blower was powered through double V-belts by the 9 hp engine. The fan speed/engine speed ratio was set by pulleys at 1.35 to permit increased fan speed for greater air movement. A lever operated idler pully was used as a clutch to engage the fan drive. The fan was connected to the back of the collector head by a 12-in. diam. furnace pipe and elbows.

The collector was constructed from a 27-gal. galvanized iron garbage can of approximately 18-in. diam. The increased diameter of the collector over the inlet was designed to decrease the air speed within the collector which would reduce the danger of damaging the insects in the collector. An 11-in. by 18-in. electrical box door was fitted into the top of the collector to permit easy access within the collector. The lid of the collector was held in place by springs, and the collector inlet from the head was fitted to it. The collector inlet was made of 12-in. diam. flexible rubber-canvas hose. Two spring clips and a hook were set in the collector to hold a 15-in. diam. sweep net mounted in a standard iron hoop directly in front of the collector inlet. The nets could easily be changed through the electrical box door (Figure 6). Single nylon sweep nets were used and no attempt at rough sorting of debris through multiple nets (as suggested by van den Bosch *et al. op cit.*) was made.

The collector head was constructed of 1/4-in. plywood reinforced with light gauge metal at the edges (Figure 7). The head tapered laterally from the 12-in. collector inlet in back to a 51 5/8-in. wide opening in front and tapered vertically from the collector inlet to a 1 3/8-in. long opening (this is the final design and gave an opening of approximately 71 $in.^2$). The opening was positioned parallel to the ground. This was done primarily to facilitate collections in small plants (spring adults of the cereal leaf beetles in young wheat, for example). The head was mounted on parallel arms lifted by a hydraulic cylinder powered from the hydraulic pump through a 2-way valve. The opening of the head could be positioned from 1 1/2-in. to 22-in. above the ground.

Figure 6. Top view of the collector showing the location of the net.

Figure 7. View of the collector head.

OPERATION

The machine is transported on a small tilting trailer fitted with two automobile transporter loading ramps. Two men are required in the loading operation because of safety reasons. One man can operate the machine once unloaded, but it was found more convenient for two men to work with the machine. One man would drive the machine and the other man would tend the nets and cages.

The machine was used during the 1973 season to collect large numbers of cereal leaf beetle adults and larvae, alfalfa weevil adults, and tarnished plant bug adults. The method developed for these collections was: a) adjusting the engine speed and head height; b) place an empty net in the collector; c) run a long swath (up to one mile in length) with the device; d) empty the contents of the net into bags or cages of 16-in. cubed covered with 32-mesh screen; e) transport the bags or cages to the laboratory either for immediate sorting or for storage at 38° F; and f) sorting the desired insects out using aspirators operated from a vacuum pump.

Operating the machine proved generally satisfactory. The machine was operated during the 1973 season with a minimum of maintenance and without breakdowns in the field. There were some defects. The narrow wheel base and rigid suspension tended to cause the device to tilt on uneven ground. The machine can be operated comfortably at speeds up to 3.4 mph on level ground, 2 mph on fairly even ground (such as a cultivated field), and at 1.4 mph in rougher lands (such as weed borders or old meadows). A wider wheel base (perhaps 42 in.) and a single point rear suspension would reduce the tilting problem. The machine also tended to slip in wet soils. Wider tires and a more even weight distribution should reduce the slippage problem.

The length of the swath traveled before emptying the net depended on the amount of trash picked up in the net. Trash was excessive in one test of the machine (see below) and was also heavy when the machine was used to collect tarnished plant bugs in a mixture of old grain stubble, clover, and weeds. The trash in the latter instance caused some damage to the wings of the bugs. A coarser net to screen out trash as used by van den Bosch *et al*. (*op*. *cit*.) could be used to reduce the amount of trash trapped in the collecting net.

Emptying the net and replacing it with an empty one was done within one or two minutes. The insects, even such fragile ones as the lacewing, *Chrysopa oculata* Say, usually appeared undamaged after collection by the machine. Survival of the cereal leaf beetle adults and alfalfa weevil adults collected in the machine was very good. The air moving through the net removed much of the water picked up when collecting in wet vegetation. There was little damage from moisture damaging the wings or sticking insects to the net, such as occurs with the sweep net, when the machine was used. The machine caused very little damage to the crop. The dividers in front of the wheels reduced tearing of the leaves, the wheel marks were light and very transitory even in heavy vegetations.

COSTS

The machine was made of materials on hand and salvage materials as well as new or used materials that were specially purchased. The machine also went through several major modifications during the period of its development. Cost of materials that were actually used for its construction cannot, therefore, be accurately determined. The prices listed in Table 1 are either the actual price paid for materials purchased specifically for the machine, or are current list prices for the materials. The machine was entirely made in a shop containing hand tools, welding equipment, and some common power tools. No precision machinery or specialized equipment was needed. The work was done principally by the author; labor costs are not included.

The best estimate of cost of operating the machine is a maximum of $0.20/A. The work-day with the machine is about 6-7 hr. of an 8-hr. day. At a speed of 2 mph (second gear at 2750 rpm engine speed) the machine will collect from about 6.26 acres in a 6-hr. work day. Allowing a salary of $2.70/hr. for two men (as seems desirable with the machine) the cost of collecting is about $7.10/A with

TABLE 1. Estimated costs for construction of a vacuum mass insect collecting machine.

Item	Cost
Hydraulic motor	$ 86.00
Gasoline engine	163.00
Pump-reservoir unit	110.00
4 Wheel assemblies	100.00
1 Transaxle	15.00
Hydraulic hose	30.00
Sprockets and chain	40.00
Control valve	30.00
Flow divider valve	45.00
Seat	10.00
Furnace pipe	20.00
Plywood	20.00
Iron and pipe	100.00
Fan	158.00
Steering gear	10.00
Hydraulic cylinder	25.00
Trailer	170.00
Misc. (fittings, pulleys, belts, bolts, paint)	150.00
	$1282.00

the machine. The best estimate for collecting with sweep nets is that one man collects about 0.61 A/hr. with a 3 to 4-hr. work-day. Two men with sweep nets at the $2.70/hr. noted above can collect from 4.88 A/work-day; a collecting cost of $8.85/A.

The difference in operating costs between the machine and the sweep net is small, and depreciation of the machine would probably eliminate the difference completely. Modification of the present machine (especially greater stability to permit higher speeds as noted below) would increase the capacity of the machine. The machine will collect more insects per area (an average of threefold increase) than the sweep net. The cost per insect collected by the machine could be less than one-third that of the sweep net. The machine can also be used in stubble and seedling grains, under weather conditions that would limit sweep nets, and the machine could also be used longer per day than the sweep net because of its reduced operator fatigue. The machine can, therefore, be used in situations where time for collecting is limited.

FIELD TRIALS

A listing of the insects collected with their vacuum devices were given by both van den Bosch _et al_. (_op_. _cit_.) and Stern _et al_. (_op_. _cit_.), but quantitation of the effectiveness of these devices against different types of insects was not cited by these authors. Maki (_op_. _cit_.) found that the portable vacuum collecting device he used was selective in its sampling of different species of insects. A series of tests were made to compare the present vacuum device with the sweep net. A range of insects was obtained by testing the device in alfalfa, a crop with a diverse insect fauna (Maki op. cit.; Ruppel in press). The tests were made in early- and mid-season and in stubble and heavy growth to obtain an idea of how the machine would operate under diverse conditions.

PRELIMINARY FIELD TESTING

A preliminary field test of the machine was made on 17 May 1973 in a new stand of vigorous, but weedy alfalfa near Mason, Michigan. The alfalfa was about 15 in. tall; 2:00-4:00 p.m.; air temperature 57° F; wind N-NW at 10 mph with gusts to 20 mph; partly cloudy with a brief period of hail and rain; soil moist; plants wet from rain.

The machine was first tried by taking several long swaths at 1.4 mph, 2750 rpm engine speed, and with the head in the upper part of the alfalfa. The more abundant insects collected, as noted by examination in the field were: alfalfa weevil adults and a few grubs; ladybeetles; syrphid flies; *Nabis* sp.; tarnished plant bug adults; spiders; leafhoppers; *Chrysopa* sp.; cereal leaf beetle adults; braconids (all parasitic Hymenoptera); pea aphid, *Acyrthosiphon pisum* (Harris); honey bees, *Apis mellifera* L.; flies; gnats; and weevils other than the alfalfa weevil.

Sweep net collections made at the same time showed the same range of insects as the collections. The sweep net collections were very wet and the insects were stuck together with moisture. The insects in the collections were clean and dry and seemed to be in generally good condition. The machine was then tested at 2.0 mph with the head near the upper part and about 4-5 in. deep in the alfalfa. The other adjustments were as noted above. Both the increase in speed and increase depth in the alfalfa seemed to increase the number of insects collected. A test was attempted with the machine operated at 3.4 mph. The field was rough and the higher speed was too fast for easy handling of the machine.

The machine proved to be easily adjusted for head height and speed and only a few minor problems with its operation were found in these trials. A 400 ft. long swath with the machine was made after the mechanical adjustments had been made. The machine operated satisfactorily in this test and a very large mass of insects was collected.

The cool, wet weather at the time of these trials made net sweeping difficult and unpleasant for the collector and yielded wet, damaged specimens. It is doubtful that mass collection by sweep nets would have been attempted under the test conditions. The machine yielded specimens in excellent condition without undue operator fatigue. It is apparent that the machine can be used under conditions that would limit mass collection with sweep nets.

TEST OF 17 MAY 1973

Four pairs of plots were laid out in the field and conditions noted in the preliminary field testing. Twenty sweeps with a sweep net were made in one plot of each pair and the other plot was collected using the machine operated at 2.0 mph, 2750 rpm engine speed, and the head about 4 in. deep in the alfalfa. The collections were processed and counted as outlined by Ruppel (*op. cit.*).

Seven taxa (see Table 2) were found in sufficient numbers to yield reliable information. The data for "other weevils" and pea aphids were analyzed using a Chi^2 test for heterogeneity. The numbers of the other insects were too low for this test, and the data of the 4 replications of each treatment were pooled and analyzed using the pooled Chi^2 test with the adjustment for small collection sizes.

The results show that the machine gave significantly higher numbers of the different insects than the net (Table 2). With the exception of the "other weevils" (a complex of species from the weeds in this field), however, the number of insects collected are too low to put too much confidence in the results. Also, as noted, the weather was very unsuitable for net sweeping. This test was encouraging as it indicated that the machine would collect such varied insects as pea aphids (small, slow moving) and tarnished plant bug adults (medium-sized, active) at least as well as the sweep net.

TABLE 2. Mean number of insects collected with a sweep net and with a vacuum collector; 17 May 1973.

Insect	Collecting method	Mean no. per sample	Ratio collector/net
"Other weevils", adults[a]	Net	37.75	3.25
	Collector	122.75**	
Alfalfa weevil, adults	Net	2.00	3.38
	Collector	6.75**	
Tarnished plantbug, adults	Net	1.75	3.43
	Collector	6.00**	
Nabids, adults	Net	1.75	5.14
	Collector	9.00**	
Pea aphid, all stages	Net	1.75	5.29
	Collector	9.25**	
Ladybeetle, adults	Net	0.75	7.00
	Collector	5.25**	
Spiders, all stages	Net	0.50	8.50
	Collector	4.25**	

**Highly significant difference between means.

[a]Weevils other than the alfalfa weevil.

TEST OF 11 JULY 1973

A test comparing the collector with the sweep net was made near Hickory Corners, Michigan, at 7:00-9:00 p.m. on 11 July 1973. The alfalfa stand was good, but decreased in vigor and increased in weediness toward the center of the field. The alfalfa was about 22 in. tall near the edge and about 15 in. tall near the center. The air temperature was 70° F; sky clear; plants and soil dry; wind calm. The experimental design and analysis were the same as described above for the test of 7 May 1973. The machine was operated at 2.0 mph, 2750 rpm engine speed, and with the head positioned about 14 in. above the soil.

The head of the collector did not enter the shorter alfalfa in the fourth replication in this test. The fourth replication was, therefore, dropped from the analysis. Some means of adjusting head height while operating the collector was needed, and the hydraulic cylinder adjustable by the operator was subsequently added to the collector.

Eleven insect taxa were collected in sufficient numbers to give reliable information (Table 3). With the exception of the meadow spittlebug adults, Philaenus spumarius (L.), grasshopper nymphs, and "other leafhoppers" (the last having low numbers), the collections obtained with the collector were significantly larger than those obtained with the net. The differences range from nearly equal (the grasshopper nymphs) to a 8.71-fold increase with the collector

TABLE 3. Mean numbers of insects collected with a sweep net and with a vacuum collector; 11 July 1973.

Insect	Collecting Method	Mean no. per sample	Ratio collector/net
Grasshopper nymphs	Net Collector	21.67 20.00 ns.	0.92
Meadow spittle-bug, adults	Net Collector	20.33 26.33 ns.	1.30
Tarnished plant-bug, adults	Net Collector	55.67 102.33**	1.84
"Other leaf-hoppers," all stages[b]	Net Collector	4.00 8.33 ns	2.08
"Other mirids," all stages[a]	Net Collector	3.67 8.00*	2.18
Nabids	Net Collector	8.33 20.00**	2.40
Pea aphids, all stages	Net Collector	4.33 11.00**	2.54
Alfalfa weevil, adults	Net Collector	23.00 83.67**	3.64
Alfalfa weevil, grubs	Net Collector	96.33 368.67**	3.83
Potato leafhopper, adults	Net Collector	32.00 217.33**	6.79
Lepidopterous larvae	Net Collector	2.33 20.33**	8.71

[a] Mirids other than the tarnished plantbug.
[b] Leafhoppers other than the potato leafhopper.
ns=Not significant.
* =Significant at the 5% level.
**=Significant at the 1% level.

(lepidopterous larvae). The mean increase in all taxa was 3.29 more insects collected by the machine than with the sweep net. A Chi^2 test of homogeneity showed that the proportion of insects taken with the machine or with the net differed significantly with the different taxa. The mean increase of 3.29 is useful only as a crude index of efficiency. The insects that showed the lowest increase in numbers collected with the machine (tarnished plantbug adults, meadow spittlebug adults, and grasshopper nymphs) are medium to large-sized, active insects. Conversely, the machine was more efficient with two very different insects; the small, active potato leafhopper adults, *Empoasca fabae* (Harris), and the large, slow lepidopterous larvae. It appears that the machine may be limited in effectiveness with the faster moving, stronger insects.

A number of other taxa were taken in small numbers in this test. All taxa were taken with both the machine and the net. The weather and time of day was excellent for collecting with a sweep net in alfalfa during this test (see Ruppel *op. cit.*). The test showed that the machine collects the same range of insects as the sweep net and, with some exceptions, the machine will obtain appreciably larger collections from an equal area than will the sweep net.

TEST OF 3 JULY 1973

A comparison of the sweep net with the machine operating at different speeds was made near Mason, Michigan, on 3 July 1973. A second year stand of moderately vigorous alfalfa with few weeds was used in the test. The first cutting had been made prior to the test, and the regrowth was about 6 in. tall when collected. The air temperature was 70° F; slight W wind; sky hazy-bright; soil wet; plants dry.

Plots 50 ft. long X 10 ft. wide were arranged in randomized block design with 4 replications. Collections of 20 sweeps with a 15-in. diam. insect net were made in one plot of each replication and collections were taken with the machine operated in first gear or second gear in the other plots. The collector head was placed about 1 in. deep in the alfalfa. The machine was operated at 2750 rpm engine speed. The collections were sorted and counted as described above. The data were analyzed using an analysis of variance.

There were no significant differences between the means of the collections obtained using the net or the machine operated at either speed with the tarnished plantbug adults, all stages of nabids, other weevil adults, and flies (Table 4). The machine operated at both speeds gave significantly larger collections of alfalfa weevil adults and grubs than did the sweep net. The machine operated in first gear gave significantly larger collections of grasshopper nymphs and

TABLE 4. Mean number of insects collected with a sweep net and with a vacuum collector operated at different speeds; 3 July 1973.

Insect	Mean no. per sample		
	Net	1st Gear	2nd Gear
Tarnished plantbug, adults	4.50a	5.50a	2.00a
Nabids, all stages	13.00a	17.75a	22.25a
Other weevils, adults[a]	4.25a	7.50a	12.50a
Flies	13.25a	17.75a	16.25a
Meadow spittlebug, adults	22.25b	11.25a	20.50b
Grasshoppers, nymphs	0.75a	17.25b	1.75a
Pea aphid, all stages	90.50a	59.00a	136.50b
Alfalfa weevil, grubs	7.50a	34.50b	31.25b
Alfalfa weevil, adults	2.75a	15.00b	14.00b
Potato leafhopper, adults	2.75a	18.25b	50.50c

Means followed by the same letter are not statistically significant at the 5% level by the Duncan New Multiple Range Test.

[a]Weevils other than the alfalfa weevil.

significantly smaller collections of meadow spittle bug adults, and in second gear significantly larger collections of pea aphids than in the other treatments. The mean number of potato leafhopper adults increased significantly with each change from the sweep net, to first gear, to second gear.

This test showed that the machine is effective in stubble as well as in the taller plants used in the prior test. The same insects that proved difficult to collect with the machine in the test of 11 July also proved difficult in this test. Decreasing the forward speed of the machine increased the number of grasshopper nymphs, but decreased the number of meadow spittlebug adults. The faster moving spittlebugs very probably were able to escape the slow-moving machine while more of the slower, bulkier grasshopper nymphs were probably drawn in at the slower speed. The machine worked very well at collecting adults and grubs of the alfalfa weevil, and at its faster forward speed, the pea aphid, and was excellent for collecting potato leafhopper adults.

TEST OF 19 JULY 1973

A test to determine the effects of the speed of the machine and depth of the collector head in the crop on the collection of different insects was made near Mason, Michigan, on 19 July 1973. The alfalfa field used was the same one as the test of 3 July, but the alfalfa had grown to be about

15 in. tall by 19 July. The temperature was 85° F; moderate SW winds; hazy to overcast sky; soil surface dry; and plants dry. The plots were 10 ft. wide X 50 ft. long and were arranged in randomized blocks with 4 replications. The machine was operated in combinations of first, second, and third gear with the collector head about 4 in. and 8 in. deep into the alfalfa. Twenty sweep net collections were also taken as one of the treatments. The collections were sorted and counted as noted above. Analysis of variance were made for all treatments and for main plot (speed and depth) interaction for the combinations of machine speed and head depth.

Treatments with the head 12 in. deep in the alfalfa had been planned for this test. The first collections taken, however, picked up too large a volume of trash (mostly dropped leaves) to process and the 12 in. treatment was dropped from the test. The results show that the insects that were poorly collected by the machine in prior tests (tarnished plantbug adults and nymphs, other mirids, nabids, and meadow spittlebug adults) gave no significant differences between their means in this test (Table 5). In addition, there were no significant differences in the numbers of pea aphids nor lepidopterous larvae between treatments in this test. The coefficient of variation for both of these two insects were very high (33% and 38%, respectively), and not much confidence can be placed in these results.

TABLE 5. Mean number of insects collected with a sweep net and with a vacuum collector operated at different speeds and different depths; 19 July 1973.

		Mean no. per sample					
		1st gear 1.4 mph		2nd gear 2.0 mph		3rd gear 3.4 mph	
Insect	Net	8"	4"	8"	4"	8"	4"
Tarnished plant-bug, nymphs	1.25	1.75	5.00	4.50	5.75	3.25	3.50
Tarnished plant-bug, adults	37.25	35.25	29.50	20.00	28.25	32.50	28.50
Other mirids[a]	5.25	3.00	7.50	3.50	4.25	1.50	3.25
Nabids	11.75	9.00	18.25	12.00	15.50	12.00	12.25
Meadow spittle-bug, adults	19.25	13.75	20.25	19.25	13.00	21.25	18.75
Pea aphid	13.50	5.25	9.25	13.00	10.25	8.00	8.00
Lepidopterous larvae	0.75	2.50	6.75	8.50	3.25	3.75	2.75
Grasshopper nymphs	1.00a	4.00c	3.00bc	3.25bc	4.75c	2.25b	1.50b
Alfalfa weevil, adults	1.50a	8.50b	9.50b	6.00b	8.23b	5.00b	8.75b
Alfalfa weevil, grubs	1.75a	2.75ab	4.75b	8.50c	4.00ab	4.50b	2.25a
Potato leaf-hopper, adults	0.50a	210.75d	115.00bcd	184.75cd	58.50b	93.50bc	66.00b
Potato leaf-hopper, nymphs	0.25a	34.00e	7.50bc	28.50de	5.50bc	11.25bcd	3.75b

Means followed by the same letter are not statistically significant at the 5% level by the Duncan New Multiple Range Test.

[a]Mirids other than the tarnished plantbug.

All treatments with the machine were significantly better for grasshopper nymphs than with the sweep net. There were minor significant differences between individual treatments with the machine. The major difference, however, was the reduced collection obtained in third gear as a main plot. There were no significant differences in head depth main plots nor in interaction between main plots with the grasshopper nymphs.

The machine did significantly better than the sweep net for alfalfa weevil adults. There were no significant differences between the means of alfalfa weevil adults in the individual treatments nor main plots with the machine. There were significant differences in the means of the numbers of alfalfa weevil grubs collected in the individual treatments. The faster speed gave fewer grubs than the two slower speeds and the 2.0 mph speed was significantly better than 1.4 mph speed. The 8 in. collection depth in the alfalfa gave significantly more grubs than did the shallower 4 in. depth. There was a highly significant interaction between main plots with the combination of 2.0 mph with the 8 in. collecting depth being highly effective with the grubs.

As in the prior test, the machine proved highly effective collecting potato leafhopper adults, and also the nymphs in this test. Significantly more adults and nymphs were collected at the 8 in. than at the 4 in. depth of collection. The speed had no effect on the number of adults collected, but the slower speeds gave more nymphal leafhoppers than the highest speed. There were no significant interactions between speed and depth of collections with respect to either stage of leafhopper in this test. All samples taken by the machine were significantly greater than those by sweep net. There were also significant differences in the means of both stages of the leafhopper collected in the individual treatments with those taken at the 8 in. depth at the slower speeds being especially high.

DISCUSSION

The tests show that, while specifically designed for the collection of the cereal leaf beetle adults, the machine will collect as wide a range of species as the sweep net. The increase in effectiveness of the machine over the sweep net varies with the species. The machine was excellent for collecting potato leafhopper adults and nymphs and alfalfa weevil adults and grubs, and did well with lepidopterous larvae, pea aphids, mirids other than tarnished plantbug, and leafhoppers other than the potato leafhopper. These species represent a wide diversity from the small, active potato leafhopper to the large, slow lepidopterous larvae. The effectiveness of the machine with the potato leafhopper was outstanding and, considering its design, was unexpected. Apparently, the leafhoppers are light enough to be sucked into the collector head in flight.

The machine was poorest with the tarnished plantbug adult, meadow spittlebug adults, nabids, and grasshopper nymphs. These are medium to large, active insects that were able to escape the collector head. The use of wide funnel nets, as used by Stern _et al_. (_op_. _cit_.) would probably be more effective with such insects than the narrow opening used on this machine. It should be noted that, while not as effective as with other species, the machine did satisfactorily collect large numbers of tarnished plantbugs for testing. The present machine could be altered to use a funnel shaped net by replacing the head with a tube connected to a net by large diameter furnace pipe. A scoop type head of the type used by van den Bosch _et al_. (_op_. _cit_.) could be adapted to the present device by simply fastening a properly formed piece of sheet metal under the present opening on the head. The last two tests show that the results of some species (_viz_. grasshopper nymphs) can be improved somewhat by adjusting the speed or depth of collection of the collector head. Ignoring the importance of the specificity of the machine (and, especially, its huge differences between it and the sweep net with the potato leafhopper), the overall ratio of insects collected by the machine over the sweep net is 3.77-fold. This represents a real reduction in cost of collection per insect over the use of the sweep net.

The tests also show that the machine can be used in a variety of conditions of crop and weather. The cold, wet weather of the test of 17 May would have discouraged sweep net collecting and would have resulted in many specimens damaged by moisture in the nets. The machine did very well under these conditions as well as collecting in both the short stubble on 3 July and the heavy growth of 19 July. Ruesink (1970), Maki (*op. cit.*) and Ruppel (*op. cit.*) have shown how weather, time of day, and other factors influence sampling of insects. Knowledge of how such factors influence the collections of a specific insect could be used to increase the efficiency of its collection. The objective of the present test was to compare the effectiveness of the machine with that of the sweep net. The results with specific insects reported here were influenced by these factors, of course, and could be quite different under other circumstances. The trash picked up by the machine in the test of 19 July points up a problem. This problem could be reduced by using a coarse net to catch the trash as done by van den Bosch *et al.* (*op. cit.*).

SUMMARY

A self-propelled machine for the mass collection of insects was developed. The machine operates by a vacuum from a fan drawing insects at high velocity through a narrow opening into a net in a wide chamber where air velocity is low. The fan and collector are mounted on a frame that is propelled by a 9 hp engine at speeds up to 3.4 mph. The

device is reasonably low in cost (about $1300), easily transported, and relatively trouble-free in operation. It is small enough that it causes a minimum damage to crops where used.

The machine was designed primarily to collect adults of the cereal leaf beetle, Oulema melanopus (L.). The machine can collect from about 6.26 acres during a normal work day; an estimated 2.44 acres/day can be collected with a sweep net. The per acre costs of operation and labor with the device ($7.10) are nearly as high as the labor costs with sweep nets ($8.85). The effectiveness in collection with the machine varies with the species. The machine was less effective with the medium to large sized active insects than with other types. The machine collected an average of 3.77-fold the number of insects per area collected as did the sweep net. The per-insect cost with the machine is appreciably less than with the sweep net. The machine can also be used under conditions that would hamper the use of sweep nets.

The machine proved easily adaptable to a wide range of collecting conditions. With modification, the machine should meet the needs for a small, easily transported mass collecting device for many entomological studies.

LIST OF REFERENCES

LIST OF REFERENCES

Castro, T. R., R. F. Ruppel, and M. S. Gomulinski. 1965. Natural history of the cereal leaf beetle in Michigan. Michigan Agric. Expr. Sta. Quart. Bull. 47(4):623-653.

Dietrick, E. J. 1961. An improved backpack motor fan for suction sampling of insect populations. Journ. Econ. Entomol. 54(2):394-5.

Dietrick, E. J., E. I. Schlinger, and R. van den Bosch. 1959. A new method for sampling arthropods using a suction collecting machine and modified Berlese funnel separater. Journ. Econ. Entomol. 52(6):1085-1091.

Hills, O. A. 1933. A new method for collecting samples of insect populations. Journ. Econ. Entomol. 26(4):906-910.

Johnson, C. G., T. R. E. Southwood, and H. Entwistle. 1955. A method for sampling arthropods and mollusk from herbage by suction. Nature 176:559.

Kirk, I. W. and D. G. Bottrell. 1969. A mechanical sampler for estimating boll weevil populations. Journ. Econ. Entomol. 62(5):1250-1251.

Maki, J. R. 1965. A comparison of sampling methods used in field pesticide side effect studies. Michigan State University; M.S. thesis. 34 pages.

Parencia, C. R. 1968. Control of cotton insects with an insect-collecting machine. Journ. Econ. Entomol. 61(1):274-279.

Riley, C. D., A. S. Packard, and C. Thomas. 1876. First annual report of the United States Entomological Commission. Govt. Printing Off., Washington, D. C. 477 pages.

Ruesink, W. G. 1970. Sweep net determination of population densities of the cereal leaf beetle, Oulema melanopus (L.). Michigan State University M.S. thesis. 49 pages.

Ruppel, R. F. (in press). Diurnal sampling of the insect complex of alfalfa. Great Lake Entomol.

Schroder, R. F. W. 1970. A modified suction machine for sampling populations of alfalfa weevil on alfalfa. Journ. Econ. Entomol. 63(4):1329-1330.

Stern, V. N. 1961. Further studies of integrated control methods against the Egyptian alfalfa weevil in California. Journ. Econ. Entomol. 54(1):50-55.

Stern, V. N., E. J. Dietrick, and A. Mueller. 1965. Improvements on self-propelled equipment for collecting, separating, and tagging mass numbers of insects in the field. Journ. Econ. Entomol. 58(5):949-1091.

van den Bosch, R., E. I. Schlinger, E. J. Dietrick, K. S. Hagen, and J. K. Halloway. 1959. The colonization and establishment of imported parasite of the spotted alfalfa aphid in California. Journ. Econ. Entomol. 52(1):136-141.