Project No. 80-R2
(Continuation of Project No. 79-ZD)

Cooperator:
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Davis, California 95616

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Project: Tree and Crop Research
Improving Pesticides Application Methods (UCI-MORSC Project)

Objectives: To apply new technology of formulations and application mechanisms to pesticide application in order to increase the level of deposits in the treated area and to decrease losses outside of the specifically treated fields.

Progress: A new generation of liquid atomization techniques and mechanisms, including use of pulsed jet atomizers, viscoelastic additives, and electrostatic charging is available for development and adaptation to spray application and control for pesticide application to a variety of crops including rice, cereal grains, cotton and vegetable crops and also to orchard and vine crops.

In 1980 this plan will include (1) laboratory and greenhouse studies followed by field tests and application accountancy (of losses to air, water and soil) using special polymer additives and drop size control spray nozzles and (2) further development and wind tunnel testing of the new pulsed jet system with airfoil section.

This project had a projected total cost of $29,910 for the first year, $18,716 of which was subscribed as of November 28, 1979 by 17 California agricultural industries. The project is expected to get underway early in 1980.

Plans: In 1981, plans include (1) testing of the maximum drop size control pulsed jet system in the field, (2) further greenhouse studies on controlled drop size, (3) use of various additives and tests on biological responses, and (4) field plot studies of the aerodynamic section pulsed jet system for drift control.

Almond Industry Participation $1,500

UCI MORSC

UNIVERSITY OF CALIFORNIA & INDUSTRY

MARKETING ORDER RESEARCH STEERING COMMITTEE

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AGRICULTURE CALIFORNIA'S No.1 INDUSTRY

February 5, 1981

File 901-BF

to: CHAIRMEN, MANAGERS and RESEARCH DIRECTORS of
UCI-MORSC Participating Organizations

Attached for your study and files is year end report relating to

PROJECT UCI-1, IMPROVING THE EFFICIENCY OF PESTICIDES APPLICATION METHODS TO INCREASE PESTICIDE EFFECTIVENESS AND DECREASE ENVIRONMENTAL PROBLEMS

by project leaders N. B. Akesson, W. E. Yates and R. W. Brazelton, Agri. Engineering Dept., University of California, Davis.

This report is submitted in accordance with Memorandum of Understanding between The Regents of the University of California and UCI-MORSC. The following organizations supported the first year plan in the total amount of $24,716:

Alfalfa Seed Producers Research Advisory Board; Almond Board; Avocado Commission; Dry Bean Advisory Board; Beet Growers Association; Celery Research Advisory Board; Planting Cotton Seed Distributors; Curly Top Virus Control Board; Dried Fig Advisory Board; Iceberg Lettuce Advisory Board; Melon Research Board; Milk Producers Advisory Board; Olive Administrative Committee; Producers Canning Cling Board; Potato Research Advisory Board; Raisin Advisory Board; Rice Research Board; Strawberry Advisory Board; Fresh Market Tomato Advisory Board; and Walnut Marketing Board.

Also enclosed is Supplementary Report prepared by Drs. Akesson, Yates and Brazelton, entitled:

GUIDES FOR IMPROVING INSECTICIDE, HERBICIDE AND CROP DEFOLIANT APPLICATION EFFICIENCY

Your comments and suggestions are solicited and welcome.

cc: J.B.Kendrick Jr., UC Statewide System
UC Commodity Research Liaison Officers
UCI-MORSC Executive Committee
J.D.Rowell, Dept. of Food & Agri.
P.H.van Schaik, U.S. Dept. of Agri.
N. B. Akesson, UC Davis
W. E. Yates, UC Davis
R. W. Brazelton, UC Davis

Francis P. Pusateri
Executive Secretary

Enclosures

First Year Annual Report 1980
UCI-MORSC Project Number 1

Improving the Efficiency of Pesticide Application Materials to Increase Pesticide Effectiveness and Decrease Environmental Problems

This is a "year end" report as specified in the Memorandum of Understanding executed March 10, 1980. Progress reports have been filed, #1 July 1, 1980 and #2 November 13, 1980.

We have proceeded in accordance with the objectives of our research proposal initiated in the fall of 1979 and funded in April of 1980. The following specific areas of research have been developed with tentative results as noted. Much of the proposed work is on-going. This year's support was largely expended on instrumentation and laboratory studies on drop size in relation to various types of atomizers, use of adjuvants in formulations, use of electrostatic charge to increase spray deposit and various methods for reducing production of spray drops under 100 micron dia. by pulsed jet and aerodynamic airfoil devices.

There have also been parallel studies in progress which have been assisted in part by support through instruments and laboratory sharing. These are application of pheromone materials in hollow fibers and studies in efficiency of pyrethroids for insect control. A smaller effort has been directed to studies on Dipel a formulation of *Bacillus thuringiensis* for insect control.

Electrostatic Charging of Spray Materials

Tests on both aircraft and ground equipment have been conducted. The first was field tested in the fall of 1979, and data on these tests were examined in the spring of 1980. The aircraft studies utilized comparative drift-loss types field tests to determine if losses from the application area were in fact reduced by the electrostatic charge. This was not a biological efficiency study, but rather a test series (4 field runs) designed to show whether drift losses could be minimized by electrostatic charge of the spray.

The field test data indicated that with the small drop size atomizers tested (8003 fan type nozzles, directed down or across the airstream, for an estimated 225 vmd or volume median diameter) there was no significant difference between electrostatic "on" or "off" on downwind air collection (in glass-fiber air samplers) or as collected on Mylar plastic fallout sheets out to 1/2 mile from the application (Figure 1). When a large drop size type spray was used (which is not effective for fungicides or insecticides) there was over a 10 fold decrease in both airborne and fallout deposits between this system and the 8003 fan nozzle system either with the charge on or off. However, this produces a drop size of 600-800 microns vmd which is useful only for certain herbicide materials.

In the fall of 1980 we were able to run a series of 4 tests on the FMC Corp. electrostatic ground operated machine. These tests were conducted similarly to the aircraft tests with no evaluation of biological efficacy of the application. Here the ground rig with 12 nozzles, designed to spray either a row or broadcast crop, applied a liquid spray of around 60 microns vmd (Figure 2). This size is close to an aerosol and capable of being transported in the air very readily for significant distances. The objective was again to conduct the tests with alternate runs of electrostatic "off" and "on." The analysis of the test data has not been completed this far, but preliminary uncorrected observations show very little or insignificant reduction in drift loss by use of electrostatic means.

Thus, at this point in our project we do not feel there is sufficient justification or promise of success to continue studies in electrostatic charging for increasing or reducing deposit losses, and we will not do any further tests unless new evidence show this to be a viable means.

Formulation Adjuvants

Probably the most accepted and most promising formulation additive is the water soluable polymer NalcoTrol. This material does not measurably increase the viscosity of the formulation, but does have an effect of drawing small drops to larger ones with an apparent reduction in the release of the under 100 micron drift-prone sizes. The field drift-loss data we have obtained thus far is only partially encouraging, and we feel that this work on viscoelastic polymers as well as studies on evaporation retardants, badly need to be corroborative in laboratory wind tunnel as well as on flying aircraft. Here we can hold tight control over the several variables in the atomization process, and concentrate on the role of formulation additives. This and a host of other atomizer and drop production studies will be greatly facilitated with the new instrument now available for our atomization work, the PMS (Particle Measuring Systems) ruby laser instrument.

Monodisperse Drop Production

We are examining a third generation of the single drop size devices on which we started several years ago. This has evolved to a very effective means for producing drops of single or very narrow band of sizes. The objective here is to reduce the production of wasteful large drops as well as the aerosol or airborne small drops which cause unwanted contamination in the area surrounding an application. Our research has evolved from a direct pulsed jet system where a pulsation in liquid emitting from a round orifice can cause the liquid to break up into single drop size (in contrast to the usually wide range of sizes) to an aerodynamic single size system patterned somewhat after the Microfoil® System. Here the circular stream emitted from the orifice is caused to break up into basically two sizes of drops. The main drop may be of 200 microns or more in dia. While the smaller drops would be of the order of 1/4 this size. When the drop stream is ejected from an airfoil section, the drops in single file formation tend to agglomorate with the little one being scavenged by the larger size (Figure 3).

This system has proved to be successful when a carefully designed airfoil with a recessed orifice is used, and pulsing appears not to be needed in order to obtain a monodispersion of drops. However, the system is limited by the fact that the drops produced are approximately 2X the orifice dia. Thus, to obtain the highly desirable 200-300 micron dia. drops, it is necessary to use orifices of 100 and 150 microns dia. This is equivalent to 5/1000 to 8/1000 inch dia. and is very difficult to use. Thus we are now trying to determine a means for obtaining these drop sizes without going to the very small orifices. Various spinning devices have been used which will in fact produce drops of 100-200 microns dia. with relatively large orifices. But these are normally in connection with a fluted disc or cupped spinner at very low flow rates. We are attempting to examine the potential for a combination of this fluted device or some form of larger orifice nozzle which will give us a narrow drop spectrum in the range of 200-300 microns.

Still another avenue of exploration for controlling drop size lies in the system of electrostatic trapping of small drops. It is possible for small drops to be separated from a larger drop spectrum by diverting them with an electrostatic charge. The rewards for any technique that would give us drop size control would be enormous, and in fact, this appears to be the most likely route for development of reduced volume and more efficient type applications for all agricultural sprays.

The Particle Measuring Instrument

The PMS system with the laser shadowgraph scanner can size and sort numbers of drops of a wide range of sizes at a rate of drop passage in excess of 150 mi./hr. (Figure 4). Thus the instrument can be placed in a wind tunnel or on the wing of an aircraft (Figure 5) and atomization processes can be studied rapidly and accurately. We were able to purchase the basic sensor unit and the electronic data anlyzer with a chart read-out which can give us a printed evaluation of the drop spectrum being viewed (Figure 6). This unit will handle drops from about 30 to 2,200 microns dia. For the smaller aerosol size drops below 30 microns, a second sensor is required which we hope we can obtain in the near future to expand our capability in this aerosol or airborne drop size regime.

We have interfaced the PMS data acquisition system with our Hewlett-Packard digital computer system. Thus we can now readily program and calculate additional parameters, print out tabular data on a standard 8-1/2 x 11 paper and produce high quality graphs on the x - y plotter. We are currently designing and building appropriate equipment for evaluating nozzles in the laboratory and on the aircraft. This involves construction of a 3 dimensional scanning system to obtain an adequate sampling pattern. Further statistical evaluation will be conducted to ensure a sound statistical basis for nozzle drop size-frequency evaluations.

The PMS unit is fundamental to any study of atomization and to the accurate evaluation of factors of design, formulation, electrostatic charge and other that affects and controls the atomization process. We are very fortunate to be able to fund purchase of this machine, in part with this project funds, and feel that it will lead us to significant developments in pesticide spray application efficiency and safety.

Biological Systems for Plant Protection

A great deal of effort and expenditure of funds has been directed to develop such biological materials, (primarily for insect control) as bacillus, pheromones and others. This is all a part of the overall integrated pest management approach and would include such items as crop sanitation, release of sterile insects and use of predators and parasites for a wide spectrum approach to pest control.

In order to apply some of these biological materials, new equipment and application techniques need to be developed. We have had an on-going project for pink bollworm control in cotton with pheromones and control of a wide variety of insects from Heleoths to mosquitoes with the bacillus and virus materials. We are continuing our project on the application of small dia. follow fibers (10 to 20 thousandth of an inch internal dia.) for holding and releasing the liquid pheromone at a given rate. This confusion pheromone gossyplure overwhelms the normal male-female attraction or lure and thus prevents development of future generations of the target insect. The fibers are difficult to apply and hold on plants, and we are at present trying to find a better system particularly for aerial application. Various wafers, microcapsules and other controlled releases matrices that may be used with gossyplure and is adaptable to transport in a liquid system will be tested as the work progresses.

We have worked with a number of virus and bacillus formulations and are presently examining certain formulations such as Dipel® for most effective drop size and delivery to the plant target. If it is found that direct flying insect contact is required of a particular formulation, then an aerosol size dispersion may be found desirable while larger drops may be best for contact with the toxicant deposited on the plant. By having control of drop size, we can alter the delivery to that size and form which is most effective for the job.

We have put together a guide for increasing the safety and effectiveness of pesticide application which encompasses the application knowledge we presently have. This information is attached and forms a basis for procedures to reduce drift losses as well as to maximize pesticide effectiveness and control of the target pest.

We would proceed with the 2nd year plan as outlined in our original proposal by further laboratory work, but with increasing field aircraft and ground application studies on specific crops and pests to improve where possible the effectiveness of pest control but with reduction in drift losses and contamination of non-target areas surrounding treated fields.

Norman B. Akesson
Wesley E. Yates
Agricultural Engineering Department
January 1981

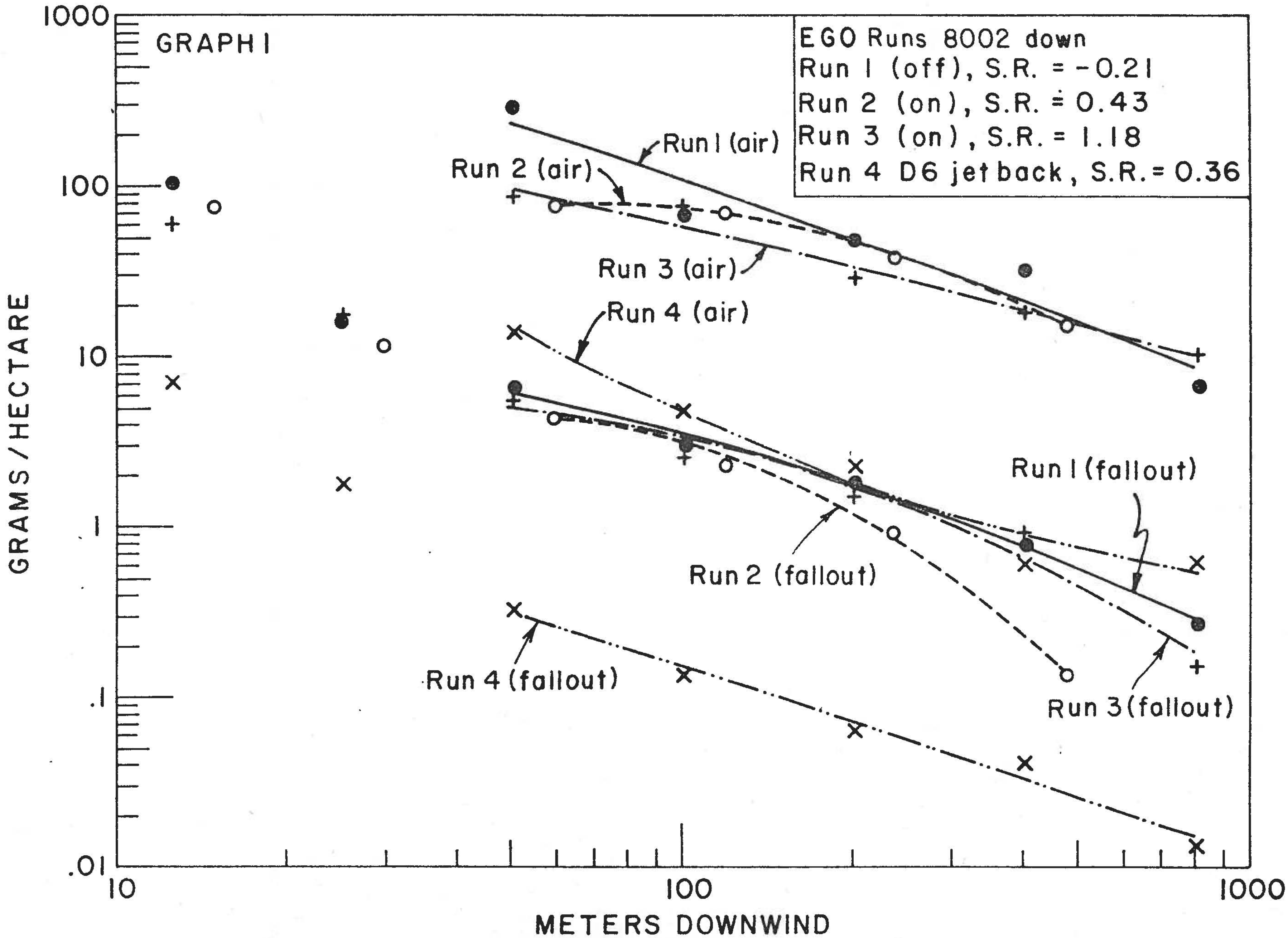

Figure 1. Electrostatic tests Pawnee Aircraft

Figure 2. Electrostatic Machine for row crops.

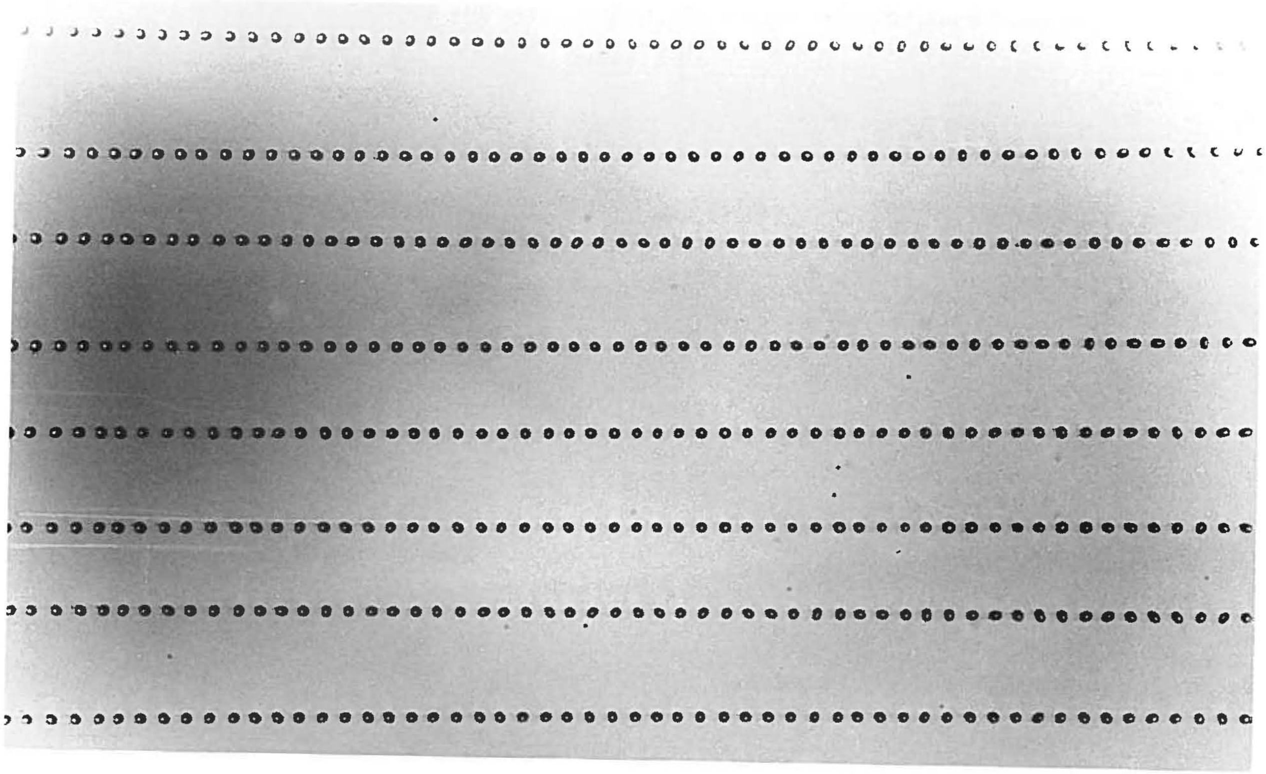

Figure 3. Monodisperse drop formation.

Figure 4. Particle Measuring Systems Ruby Laser Instrument.

Figure 5. Wing mounting for Aircraft drop size tests.

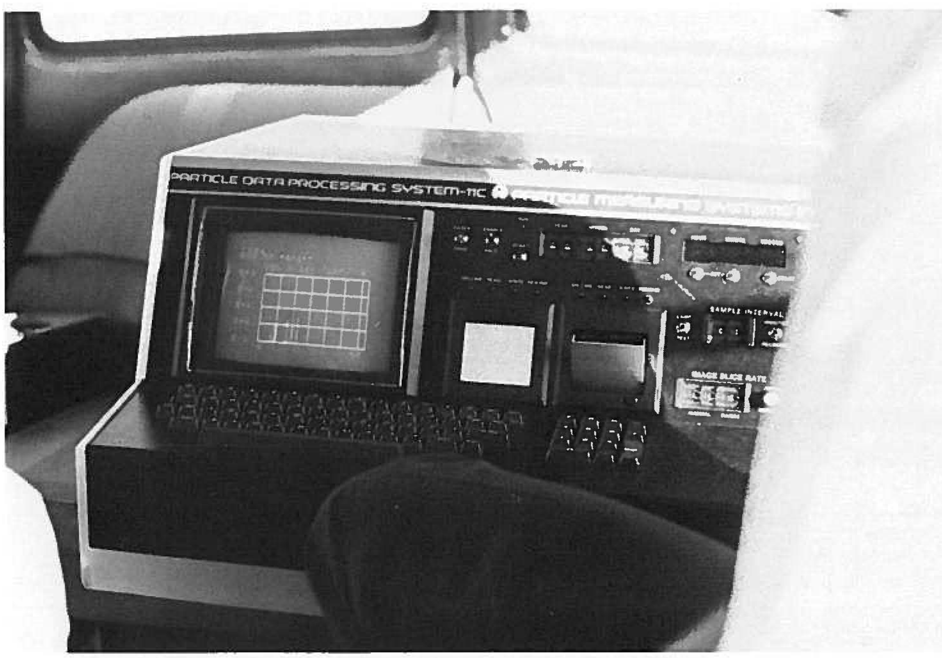

Figure 6. P.M.S. visual display of drop size distribution.

Guides for Improving Insecticide, Herbicide and Crop Defoliant Application Efficiency

Norman B. Akesson, Wesley E. Yates and Robert W. Brazelton
Agricultural Engineering Department
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Significant strides have been made during the past few years in the improvement of aerial application equipment, formulations and techniques for safe use of pesticide chemicals. This has resulted in reduced damage claims from losses of materials outside designated target areas, as well as providing greater safety for mixers, loaders and pilot applicators involved in pesticide use. However, the general public is still responding to the "horror stories" of a decade or more ago when admittedly the level of application competency among aircraft and ground applicators as well, was low and in need of considerable improvement.

Probably the most important single element of improvement in pesticide use has been the licensing of pest control advisors. This has brought a new level of professional responsibility which has had a secondary response in improving application techniques. The requirement for specific chemical (or other pesticide) recommendation also entails recommendations for the most efficient and safe method of application. Thus, a new awareness of the essential role of application effectiveness and safety seems to have resulted. The integrated pest management concepts and scouting programs as well as incentives due to increased costs for pest control have all contributed to the needed improvement in effectiveness and efficiency of plant protection operations. Chemical control still remains the basis for most satisfactory programs on agronomic crops and it is going to be increasingly necessary to learn to manage chemical use to minimize exposure and potential harm while retaining the essential benefits of these valuable tools.

Application research has generally not had the intensive and coordinated support of public agency and industry that either new chemical development or biological testing and screening has had. Thus, it is not surprising that the most frequent solution to problems that arise from the use of a particular chemical agent is either to regulate against its use or to create an environment of regulation and distrust that indirectly results in its being abandoned. Only minor consideration has been given by regulatory agencies to improved methods of application.

The basic elements involved in a given pesticide application are disarmingly simple when compared with the complex biological chain of responses that the use of the chemical can evoke. A recommendation for a specific chemical application is made. followed by the necessary purchase and delivery of material and the mixing and loading operation of the material in the spray rig. The quantity of material placed in the machine and the fixing of the rate at which it is dispersed is the basic calibration process. The crop is then treated with the expectation that the pest control function will be effective and that a minimum of undesirable side effects will occur. The application is thus projected into the future with a host of crop, chemical and pest interactions, all combining to help or hinder the effectiveness of the application. The applicator is thus pitting his skill and knowledge against the many complex and interlocking functions which interface the physical aspects, that the applicator controls with the biological responses largely out of his control. It is this aspect of pesticide use that has always constituted the largest unknown and difficult area of application research and still remains the greatest challenge today.

For example, increased insect target contact efficiency can be obtained by producing a cloud of very fine liquid drops which circulate and move through the crop plants. The losses of these small drops out of the target area are very high, but the effectiveness of insect control can also be high. If we reduce the losses by increasing the drop size we lose a measurable amount of control effectiveness. We do not know precisely what takes place or exactly what drop size, applied dosage and volume and insect contact interactions exist. But it is obvious that the mode of chemical action, insect development patterns and crop functions are all involved in a complex biological response.

The experienced operator knows that within certain limits of drop size and the intrinsic toxicity of the insecticide to the target insect, he can expect to attain a certain level of insect control. It is also known that the portion of the released spray in drops below 50 to 75 microns diameter constituate an airborne spray portion and limiting these aerosoal drops will reduce the losses or the portion of the application that does not reach the target field. The percent of spray in these small drops is in turn controlled by the spray atomizer. Thus, there is always a continual attempt being made to find an acceptable compromise between effective control and minimum losses or non-target contact.

If a translocated herbicide or a plant defoliator rather than a contact insecticide is being used, the application problem has different requirements. Now the need is only to insure the highest possible contact efficiency between chemical and target. This can generally be obtained by using large drop size sprays with sufficient liquid volume containing the herbicide or dessicant and perhaps a spreading agent to provide necessary plant coverage.

Again the application appears to be very simple, but consideration must be given to the spray additive used which may alter the wetting characteristics of the plant, in case of herbicides, or the liquid drop spreading and leaf surface coverage in case of insecticides or fungicides. Also more complicaing are the newer polymer additives which under certain use may aid in reducing the numbers of drops under 50 microns, by affecting the physical characteristics of the formulation. But these also affect the chemical responses and thus the control of the target pest.

If the machine characteristics in relation to the biological requirements are not enough, the further complication provided by local weather, both as it affects the biological and the physical aspects, adds a further dimension to a highly unpredictable system. The effect of wind velocity on the actual application is frequently overrated, probably because it is the most obvious weather factor. But also its effect on small drop size sprays or dust applications is vivid in our minds, which readily produce an image of great clouds of materials being transported downwind and out of sight. If it were possible to use relatively large drop size sprays that were control effective or were we able to remove the small drops below about 75 microns while retaining the larger drops, the clouds of transported drops would no longer appear. The larger drops would settle out in the application swath, or the extension downwind of that swath which can occur from a strong sidewind. But the airborne drift problem arises from the small drop portion (50-75 microns) of the spray and reducing or eliminating these small drops would minimize drift losses. The extended swath must always be accounted for especially from aircraft application.

The more subtle effects of weather would relate first to the presence or absence of a warm overhead air layer or temperature inversion. The closeness to the ground of this layer would provide a limited expansion depth and dilution for the released spray drops, principally those below about 75 microns which are capable of being airborne. Other weather functions, such as temperature and humidity, would affect spray evaporation rate, particularly of volatile chemicals but also affects rate of evaporation of the customary water carrier. Temperature and humidity can, of course, also affect the responses of the insect pest.

The precise knowledge required to bring all of these application factors into proper perspective, particularly as they interreact with biological responses, is admittedly limited. However, by staying within certain prescribed bounds, largely gained from practical experiences, we can apply certain machine and application techniques which can greatly reduce the chances for chemical contamination or damage while retaining acceptable pest control efficiency.

Application Guidelines

First, the recommendation for a specific application should only be made under the guidance of licensed pest control advisors or technically knowledgeable persons where licensing does not apply. Pest infestations should be monitored by scouting, and where possible, alternatives to chemical means (which include a variety of measures identified collectively as integrated pest management) should be used. Application recommendations would include:

For aircraft operations: (fixed wing)

1. Use the largest drop size compatible with the coverage required for the specific material being used. This would mean for:

   Herbicides and defoliants or dessicants: Jet spray, as produced by no smaller than a D4 (4/64) or larger than D10 (10/64) in. dia. orifices, directed with the airstream and operated at not over 40 lbs/in^2 pressure, with no fan or cone producing element in the nozzle. This will produce an average size of about 800 microns vmd.

   Insecticides and fungicides: D4 to D10 orifices with Number 46 whirlplates (or larger) directed with the air stream and not over 40 lbs/in^2 pressure. This will produce an average size of around 500 microns vmd.

If smaller drop sprays are required, which may be particularly true for the insecticide and fungicide applications, the Number 45 whirlplate can be substituted for the Number 46, but always with the discharge directed with the airstream and at not over 40 lbs/in^2 pressure. This will produce an average size of around 300 microns vmd.

The amount of active chemical in drops under 50-75 microns (airborne) will be 3-5% of the total for the jet nozzle, 5-10% for the Number 46 whirlplate with orifices D4 to D10 and 15-20% for the No. 45 whirlplate, D4-D10 orifices.

2. For helicopters operating under 60 mi/hr, the herbicide and defoliant applications can be made with the D4 to D10 with Number 46 whirlplates. For insecticides and fungicides the Number 45 whirlplate will likely be needed. But, again, it is to be noted that the nozzles should be directed back or with the airstream. The effect of helicopter downwash does not become significant until it is operated below about 25 mi/hr. When the D6 jets, for example, are directed across the airstream, the drop size spectrum contains more small drops than does the spray from a D6 orifice with a 46 whirlplate directed with the airstream.

Because the spray pattern from an aircraft is always wider than the actual usable swath, some allowance must be made for this downwind swath displacement at the boundary of the treated field. Thus, from Figure 1 the usable (flagged) swath width (solid line) was about 70 ft., but the displacement toward the right due to side wind was another 40 ft. The dashed line shows drops/cm^2. The "peaks" indicate displacement of small drops by both the rotor wake and the cross wind. Figure 2 shows the trailing out of spray swath pattern that occurs from the 8003 fan nozzles as well as from the D6-46 system on any aircraft and accounts for the recommendation that no application of a chemical be made within 250 ft. of a sensitive crop, or next to homes, schools or people. Greater distances of up to 1000 ft. or more might be required to protect a highly sensitive crop from airborne drift (not swath displacement) from such materials as the phenoxy herbicides. The swath displacement always occurs with a side wind, but the largest portion of the displaced swath will be deposited within 150-250 ft., while airborne drift can be carried for many miles. The recovery within 150 ft. downwind when using different atomization systems is shown in Figure 3. Here the D6-46 directed with the airstream, which produces a 450 micron vmd, shows an active chemical recovery of 91% in 150 ft. distance. The 8003 for nozzles producing around 300 microns vmd shows a recovery of 83% while the Micronaire R rotary atomizer at around 225 microns vmd indicates a recovery of 51%. The D6-23 on the Hughes helicopter produced a spray of about 125 μm vmd and only a 14% recovery. Thus, the drop size becomes the controlling element in the movement or displacement of material out of the target field or conversely the amount that is recovered within the target field or extended swath area.

The Microfoil R system can be used very successfully on helicopters operated under 60 mi/hr applying translocated, or other systemic materials not adverse to large drops. The Microfoil produces drops of 800 to 1000 microns of nearly all one diameter, and with only a small percent of drops smaller or larger than this size. The D4 to D10 jet system produces a vmd (volume median diameter) of 800 to 1000 microns, but with a larger percent above and below that size. The Microfoil reduces drift losses and swath displacement to a minimum, much below that of the jet system on the fixed wing aircraft, but the large drops of either of these systems are suited only to specific applications of materials and crops.

The use of formulation additives such as the polymer materials (NalcoTrol R, Target R and Air Drop R) may reduce the production of small drift prone drops, but only when properly used. The basic recommendations for the type nozzles as noted above, pressure not over 40 lbs/in^2 and always directed with the air-stream, must apply to any use of the polymer additives because the effect of high atomization shear, either from the airstream or from high pressure, breaks down the polymers.

Additional spreader or wetting agenc additives may be recommended, but these do not appear to have any significant effect on the size of drops or the size range produced, being primarily effective on spreading on and penetration of plant surfaces. These do affect the rate of evaporation and final deposited drop size.

It is notable that if the large drop size systems as recommended can be used with satisfactory control, then the acceptable application weather is no longer as restricted. In general, weather recommendations would be for:

A. Not over 15 mi/hr velocity and with consideration for the swath displacement at the downwind edge of the treated field. Waiting until a wind shift occurs to treat this edge, or allowing a minimum of 250 ft. or more clearance to sensitive areas is a good practice.

B. Specific problems of highly toxic herbicides and sensitive crops, or toxic or odiferous insecticides and defoliants applied near human and animal habitat or streams and ponds will require greater limitation.

1. Do not apply unless wind is away from sensitive areas.

2. Do not apply in over 10 mi/hr wind velocity and provide a buffer zone of minimum 1000 ft. clearance to sensitive crops, streams, ponds, homes in residential areas, schools, shopping areas and other sensitive habitat.

3. Do not apply under temperature inversions (frequently in early morning) when ceiling is below 500 ft., nor with less than 2-3 mph wind velocity.

4. Where contamination of an air basin might occur, such as in a confined valley, consideration for limiting the number of acres treated in a given day can aid in reducing the total amount of air transported (under 50 microns diameter) chemical and thus reduce the total exposure levels.

Ground Equipment

Work has also been done with improvement of ground sprayers particularly air-carrier or blower-type sprayers which produce chemical drift losses equal to or greater than aircraft equipment. Again, the portion of the spray in small drops causes the drift loss problem. Thus, where air-carrier equipment is used with mildly toxic chemicals the D4 to D10 orifice with no smaller than Number 46 whirlplates should be used, directed with the airstream and operated at not over 40 lbs/in^2.

Hydraulic boom-nozzle systems for highly toxic herbicide materials and minimum losses should be operated at low pressures of 20-30 lb/in^2 for fan nozzles or at approximately 1 lb/in^2 with a deflector or flood-type nozzles for minimum drift loss. For less toxic chemicals, fan and cone nozzles no smaller than 0.2 gal/min flow rate should be used with no higher than 40 lbs/in^2 pressure. This might be fan nozzles no smaller than the 6502, 7302 or 8002 and cones no smaller than D3-25 or TX12.

The same weather restrictions should be applied to highly toxic chemical applications by ground as by aircraft. Since small drops (under 50 microns) can be moved around an air basin and carried for many miles, the ground equipment operated under high pressure with small nozzles can put a large percent of air transportable drops into the air to be widely dispersed under temperature inversion and confined valley conditions.

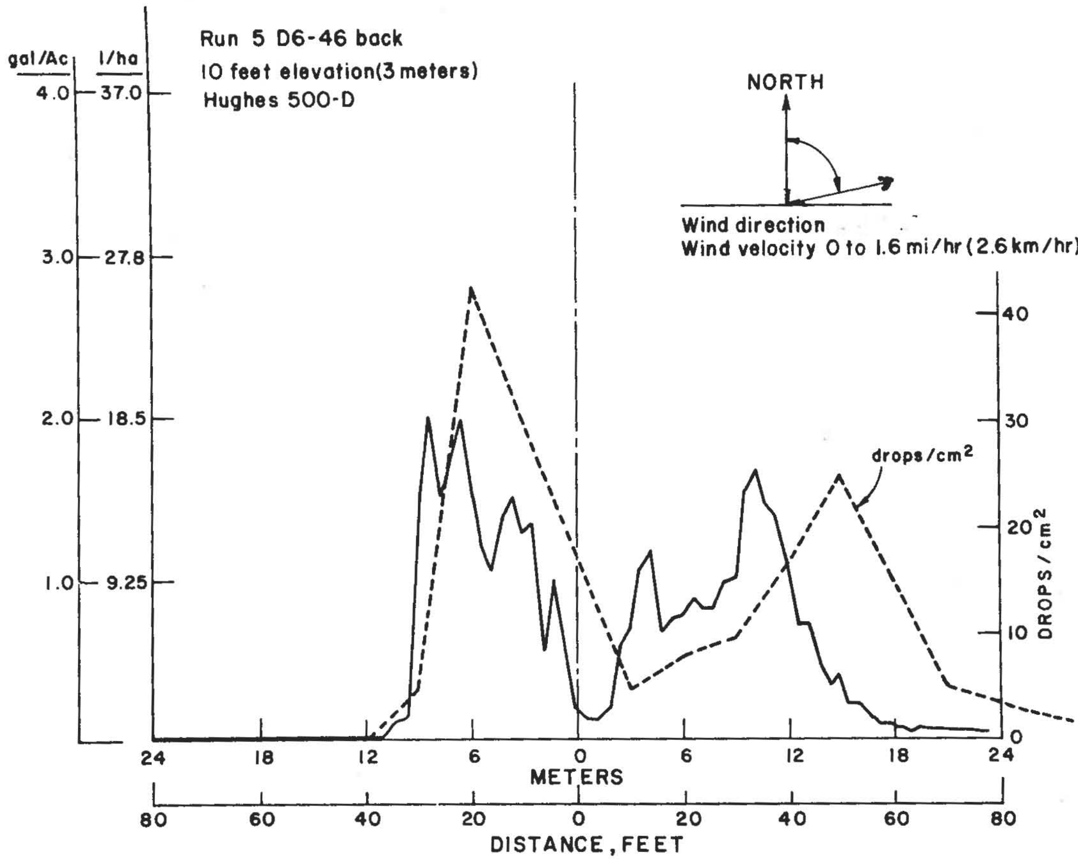
There are several further developments in application equipment which would be applied to further reduce losses from application sites. Pulsed-jet (single drop size) devices for both aircraft and ground equipment could be produced if the limitations of very small orifices (0.1 to .005 inch) could be accepted. Electrostatic charged sprays, either for obtaining greater deposit efficiency, or for removal of small drops from the spray stream are being investigated and could be available if the demand justified the cost of producing these.

Summary

Pesticide application safety and precision of application placement has increased tremendously in the past few years. Recovery of aerially applied chemicals is high (Figure 3) when large drop size sprays are used. But even with smaller drop size sprays as produced by fan nozzles (not recommended) on aircraft, the recovery in the extended swath or downwind in the first 150 ft. can be of the order of 80%. If we can accept this swath displacement of 150 to 250 ft. and not permit its overlap into adjacent fields, then the losses by the airborne portion of the spray is reduced to but a few percent as shown in Figure 3. But care must be taken to keep these small drop losses in mind since damage can be caused by these when highly sensitive crops or other non-target situations exist downwind.

Even greater reduction of these losses outside treated fields can be made with new equipment, such as the pulsed-jet devices and in some cases the new spray additives (polymers) may help reduce losses. At present we can maximize safety by examining each chemical in relation to its specific application requirements and its potential for damage to non-target crops or hazard to persons and domestic animals. These application factors must be correlated to the control effectiveness of the chemical or to the complex biological responses that can occur especially as the application is altered. Obviously greater research knowledge of the biological responses is needed for the many pesticide chemicals. However, rationalization of these biological interactions with the physical application constants, such as the drop size, can be made for different groups of chemical formulations which should make possible prediction of the most effective drop size to use with a given chemical group. This could reduce, but not necessarily eliminate the need for individual application testing of specific chemicals.

The most significant application function is control of the spray drop size, not only for the average size but more precisely for the range of drops being produced on the amount below 50-75 microns dia. Correlation of drop size with field losses can be made with data presently available. But correlation with the complex biological response functions will always require that specific chemical reactions to plants and pests be examined. More information on individual chemical compound responses can, however, lead to more accurate prediction of these responses and thus to a broader understanding of the application requirements.



Run 5 D6-46 back
10 feet elevation(3 meters)
Hughes 500-D
gal/Ac
l/ha
4.0
37.0
3.0
27.8
2.0
18.5
1.0
9.25
NORTH
Wind direction
Wind velocity 0 to 1.6 mi/hr (2.6 km/hr)
drops/cm2
DROPS/cm2
40
30
20
10
0
24
18
12
6
0
6
12
18
24
METERS
80
60
40
20
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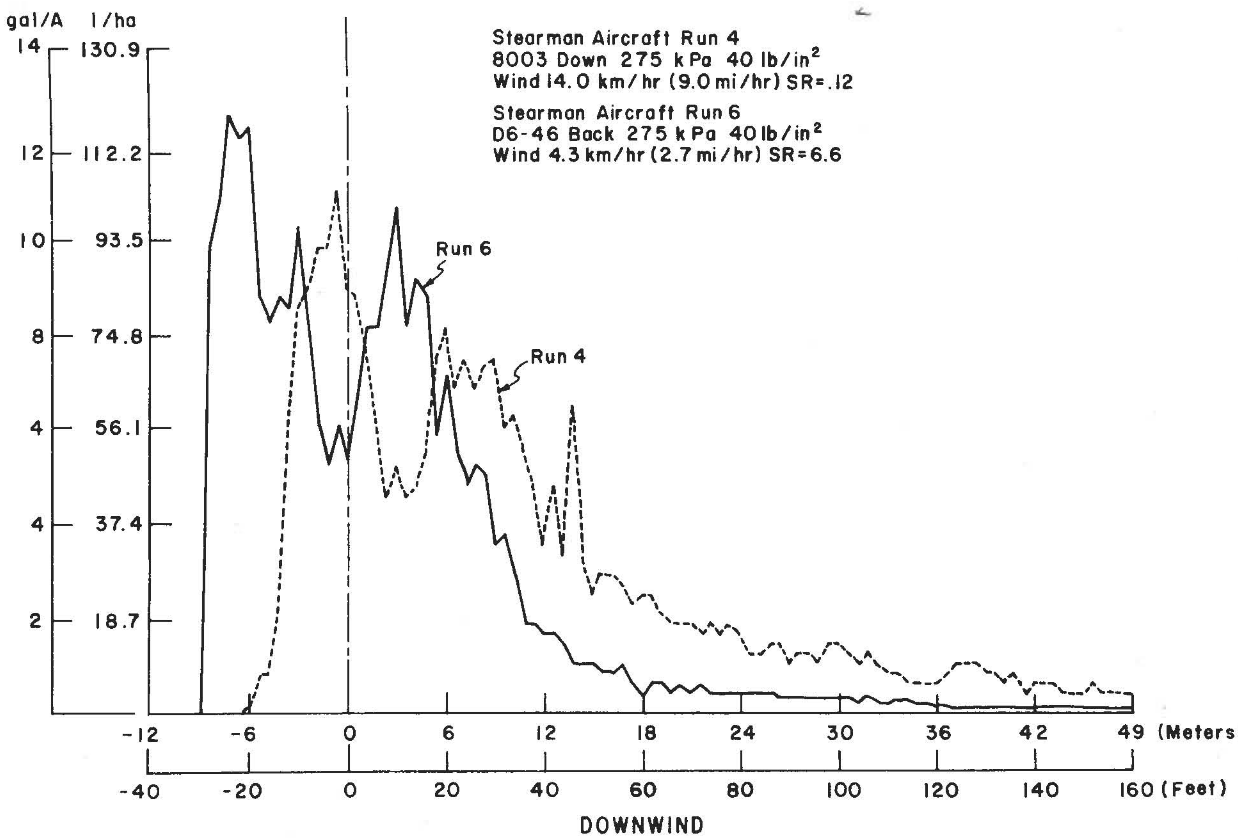
20
40
60
80
DISTANCE, FEET

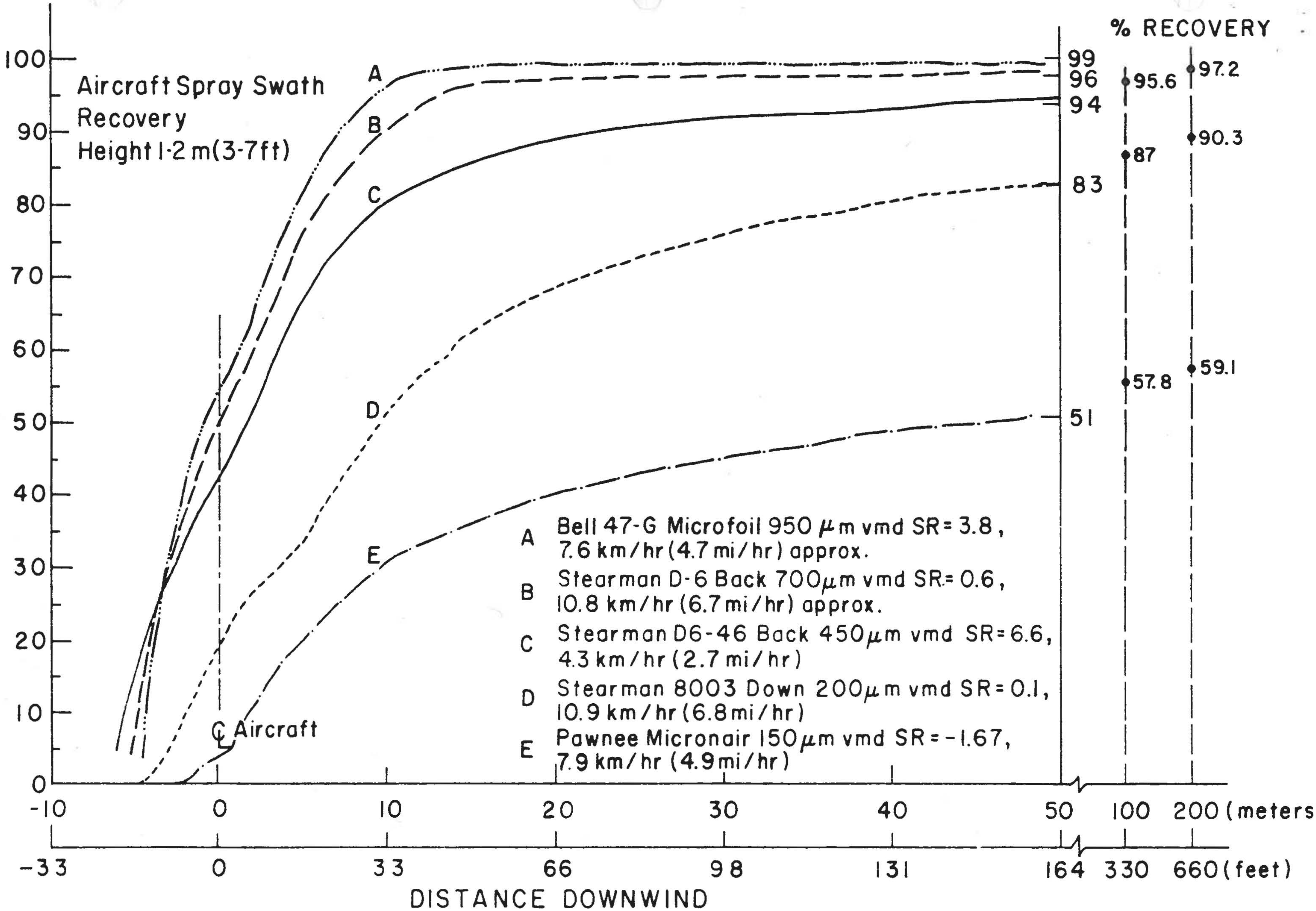
Figure 1



gal/A l/ha
14 130.9
12 112.2
10 93.5
8 74.8
4 56.1
4 37.4
2 18.7
Stearman Aircraft Run 4
8003 Down 275 kPa 40 lb/in²
Wind 14.0 km/hr (9.0 mi/hr) SR=.12
Stearman Aircraft Run 6
D6-46 Back 275 kPa 40 lb/in²
Wind 4.3 km/hr (2.7 mi/hr) SR=6.6
Run 6
Run 4
-12 -6 0 6 12 18 24 30 36 42 49 (Meters)
-40 -20 0 20 40 60 80 100 120 140 160 (Feet)
DOWNWIND

2

Figure 2



% RECOVERY
Aircraft Spray Swath Recovery Height 1-2 m(3-7ft)
100
90
80
70
60
50
40
30
20
10
0
A
B
C
D
E
99
96
94
83
51
95.6
97.2
87
90.3
57.8
59.1
℄ Aircraft
A Bell 47-G Microfoil 950 μm vmd SR= 3.8, 7.6 km/hr (4.7 mi/hr) approx.
B Stearman D-6 Back 700μm vmd SR= 0.6, 10.8 km/hr (6.7 mi/hr) approx.
C Stearman D6-46 Back 450μm vmd SR=6.6, 4.3 km/hr (2.7 mi/hr)
D Stearman 8003 Down 200μm vmd SR=0.1, 10.9 km/hr (6.8 mi/hr)
E Pawnee Micronair 150μm vmd SR=-1.67, 7.9 km/hr (4.9 mi/hr)
-10 0 10 20 30 40 50 100 200 (meters)
-33 0 33 66 98 131 164 330 660 (feet)
DISTANCE DOWNWIND

Project Progress Report
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Nutritional Value of Almond Hulls for Dairy Cows

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C-74-23

The objectives of the study are to:

1) Assess variations in chemical (nutrient) composition in hulls;
2) Evaluate relationships among hull components and nutritive value for ruminants;
3) Evaluate protein supplements for use with almond hulls;
4) Assess nutritive value of almond hulls for lactating dairy cows; and,
5) Evaluate criteria for representing nutritive value(s) of almond hulls.

Results relevant to the first objective are presented in Tables 1 and 2. The results presented in Table 1 are standard proximate analyses commonly utilized in evaluations of feedstuffs. Average values for samples of three varieties are presented in bold type and ranges in regular type. Values for crude protein (N x 6.25), ether extract, and ash are fairly consistent across varieties and samples excepting one non-pariel sample that was apparently contaminated with almond meats resulting in elevated protein and fat levels. Crude fiber is the current criterion used to evaluate almond hull quality. Crude fiber was selected as an index of shell contamination rather than as an indicator of nutritive value. Since neplus hulls are consistently higher in crude fiber, the crude fiber index clearly discriminates against this variety. It has been established that acid detergent fiber (ADF) is a superior index of nutritive value in many feedstuffs. Applicability of this index to almond hulls will be discussed below.

Results of analyses of hulls for specific chemical components are presented in Table 2. Lignin - an indigestible component of feeds - was similar across varieties. The range of values was quite high. Cellulose and hemicellulose - slowly digested feed components - values were fairly uniform. Neplus values were higher than for other varieties. Pectin and starch - readily digested carbohydrates - values were low and consistent. Soluble sugars are a major component of hulls and, along with starch, pectin, hemicellulose, and, to a lesser extent cellulose, are a major determinant of rates of digestion and fermentation. Soluble sugars decrease as crude fiber increases (Figure 1), but the relationship is clearly different for different varieties. Since soluble sugars contribute in a major fashion to the nutritive value of almond hulls and relationships between sugar and crude fiber are very different across varieties, use of the crude fiber index appears inappropriate since it unjustly discriminates against the neplus variety. No such discrimination would occur if ADF were used as the index of nutritive value (Figure 2). Note also that variability among hull samples (Tables 1 and 2; Figures 1 and 2) in sugar, ADF, and crude fiber is high. High variability in these indices clearly emphasizes the need for improved laboratory methods of estimating the nutritive value of almond hulls.

The cost of running digestion trials with cattle precludes using this approach to further evaluate indices of hull nutritive value. Therefore, hull fermentation in vitro - artificial rumen - was studied to accomplish this goal. This is a proven and far less costly approach. Results are presented in Figures 3-5. Relationships between hull crude fiber and sugar content and fermentability were virtually non-existent (Figures 3 and 4). Failure to observe a relationship with crude fiber was expected based on data presented above. However, the poor relationship to sugar content was unexpected. Apparently, variations in other fermentable hull components such as starch, pectin, hemicellulose, and cellulose compensate differences in sugar content among hull samples.

The observed relationship between ADF and fermentability is presented in Figure 5. The R^2 for this relationship is 0.56 indicating that 56% of variation in fermentability can be predicted from differences in ADF. This relationship may not be as good as one would hope but is clearly better than those for crude fiber and sugar. Digestion studies with three samples of hulls are underway. These will enable further and more sophisticated evaluation. However, at this point, it appears that ADF is the best laboratory method currently available for evaluating the nutritive value of almond hulls.

Diets used and data obtained in the performance study with lactating dairy cows are presented in Tables 3 and 4. In the experimental diets, alfalfa was replaced with almond hulls and urea to maintain constant crude protein (CP) and net energy (NE) values in the total ration. Animal performance on the three diets was essentially identical, indicating that almond hulls can comprise 25% of a dairy cattle diet without affecting performance.

Digestion trials with hulls of the three varieties were delayed because pure samples of neplus could not be obtained until this fall. The final digestion study will soon be complete.

TABLE I. HULL ANALYSIS (% OF DRY MATTER)

	Variety		
	Non Pariel	Merced	Neplus
Crude Protein	6.1	5.4	6.1
range	4.7-8.8	4.9-5.8	5.4-6.7
Ether Extract (fat)	4.9	2.5	3.2
range	1.7-12.0	2.1-3.4	2.1-5.4
Ash	6.0	7.3	7.6
range	5.2-7.0	7.0-7.7	6.8-8.3
Crude Fiber	14.3	14.3	18.2
range	12.1-16.6	14-14.8	17.4-24.9
Acid Detergent Fiber	25.7	21.2	28.1
range		20.6-22.5	24.6-35.2
NFE	68.7	70.5	64.9

TABLE 2. HULL ANALYSIS (% OF DRY MATTER)

	Variety		
	Non Pariel	Merced	Neplus
Lignin	**10.6**	**7.8**	**10.2**
range	7.7-16.6	7.5-8.4	7.9-15.6
Cellulose	**14.6**	**13.1**	**17.4**
range	12.9-18.1	12.8-13.8	15.9-20.7
Hemicellulose	**3.5**	**3.1**	**4.2**
range	2.1-4.8	2.0-4.0	2.7-6.3
Pectin	**3.1**	**2.7**	**3.3**
range	2.6-3.8	2.6-3.1	2.7-4.3
Starch	**2.8**	**2.5**	**2.8**
range	1.8-5.2	2.1-2.8	2.7-3.3
Sugar	**25.3**	**27.7**	**23.7**
range	20.8-33.7	19.6-33.2	18.5-29.4

TABLE 3. DIETS USED IN LACTATING COW STUDY

	%	CP	CF	ADF	NE
Control					
Alfalfa	61	11.6	15.3	18.3	.88
Barley	27	2.7	2.0	2.4	.50
CSM	8	3.6	1.0	1.6	.14
Total Diet		**17.9**	**18.3**	**22.3**	**1.68**
12.5% A.H.					
Alfalfa	48	9.1	12.0	14.9	.70
Barley	27	2.7	2.0	2.4	.50
CSM	8	3.6	1.0	1.6	.14
A.H.	12.5	0.6	1.9	3.5	0.16
Urea	0.5	1.4	—	—	—
Total Diet		**17.4**	**16.9**	**22.2**	**1.68**
25% A.H.					
Alfalfa	35	6.7	8.8	10.9	.49
Barley	27	2.7	2.0	2.4	.50
CSM	8	3.6	1.0	1.6	.14
A.H.	25	1.5	3.8	7.0	.32
Urea	1.0	2.8	—	—	—
Total Diet		**17.3**	**15.6**	**21.7**	**1.63**

TABLE 4. UTILIZATION OF ALMOND HULLS BY LACTATING COWS

	CONTROL	MED 12.5% A.H.	HIGH 25% A.H.
Feed Intake, kg/day	21.77	23.00	22.66
Milk Prod., kg/day	24.85	25.15	24.65
Kg/milk/kg Feed	1.14	1.09	1.09
Kg/milk/Mcal NE_M	0.68	0.65	0.67
% BF	3.20	3.20	3.23
% SNF	9.20	8.50	8.80
Body Wt., kg			
Initial	624.4	625.8	615
Final	623.4	625.2	628

Figure 1. Relationship Between Soluble Sugars and Crude Fiber in Almond Hulls

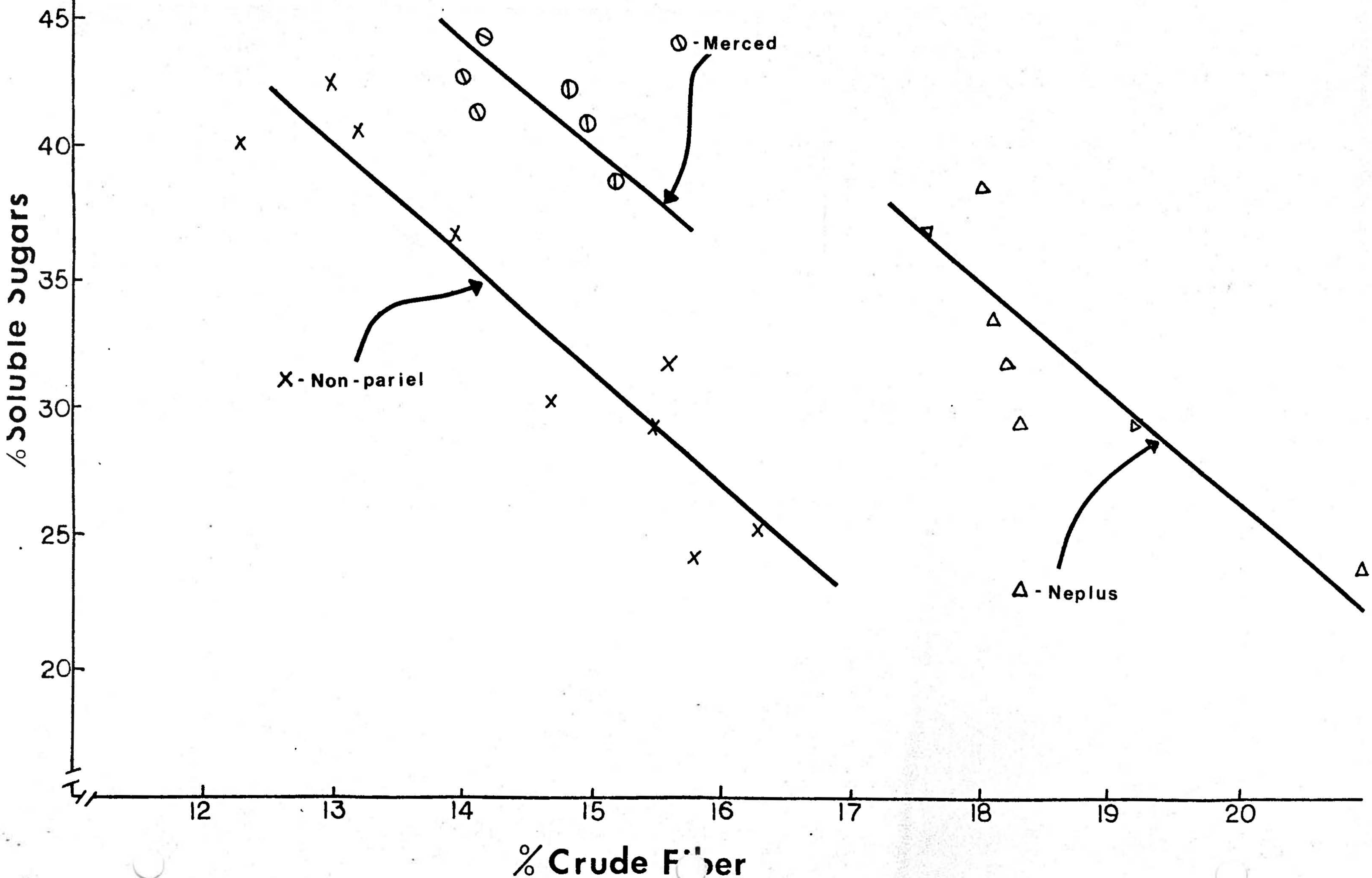
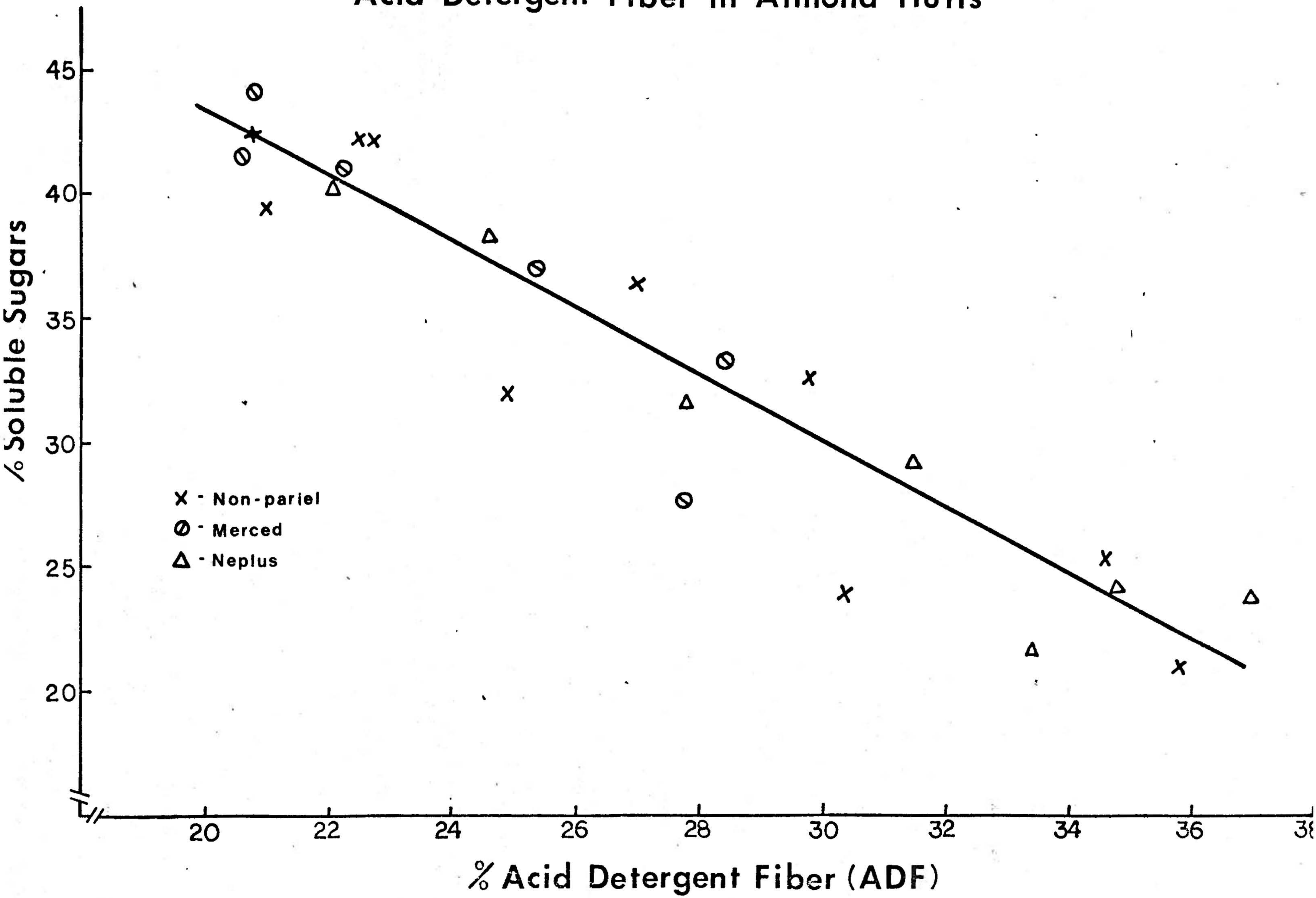
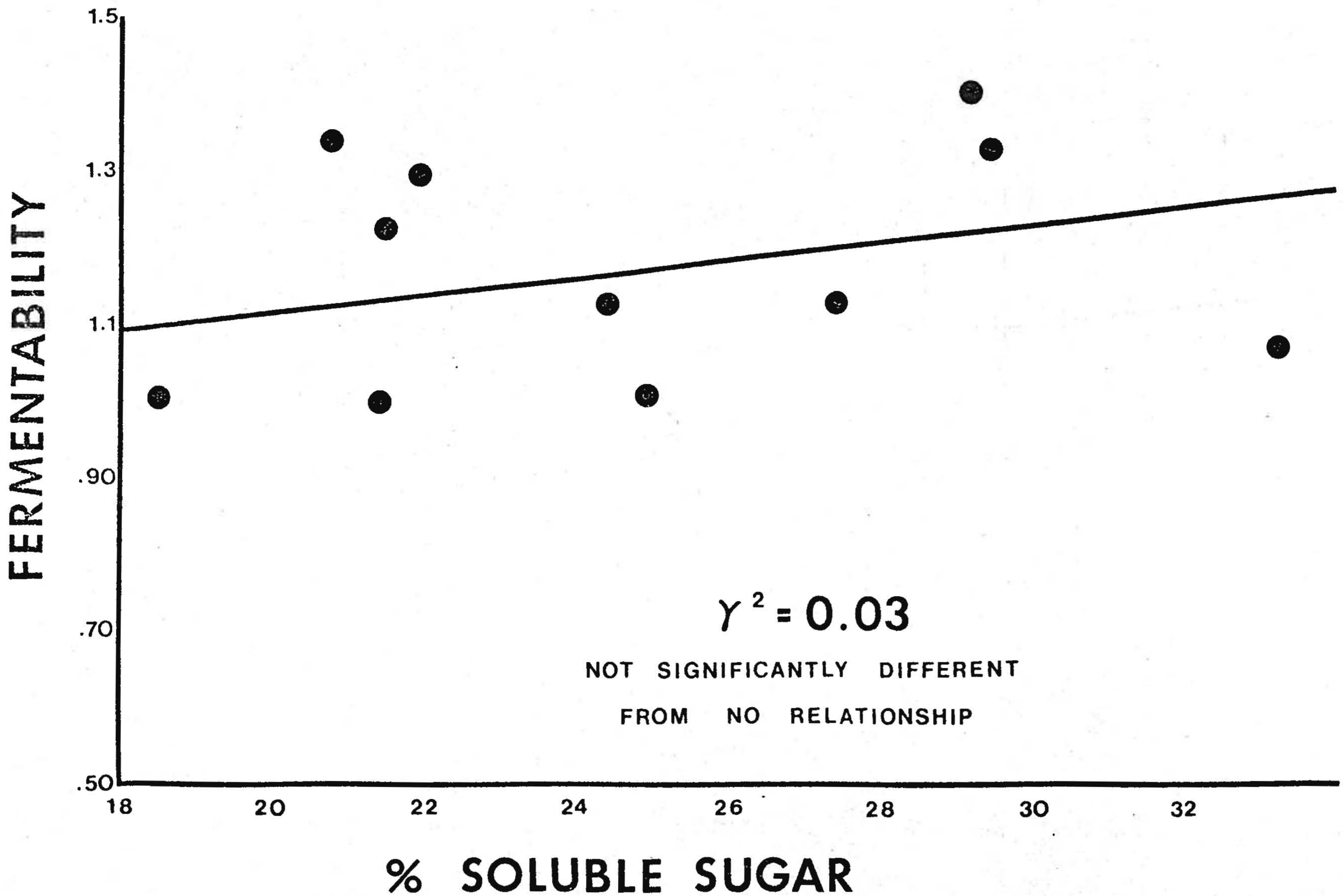
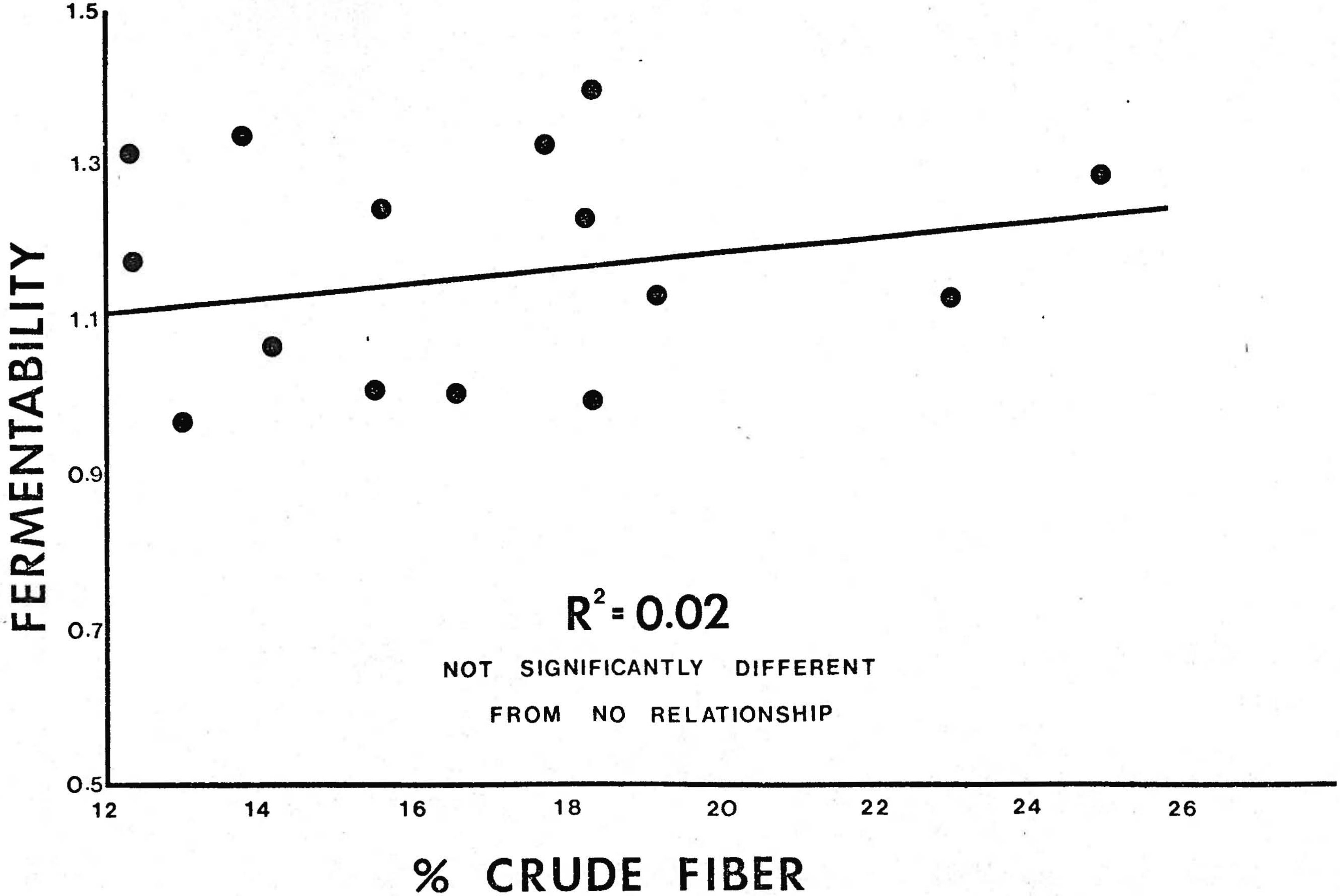


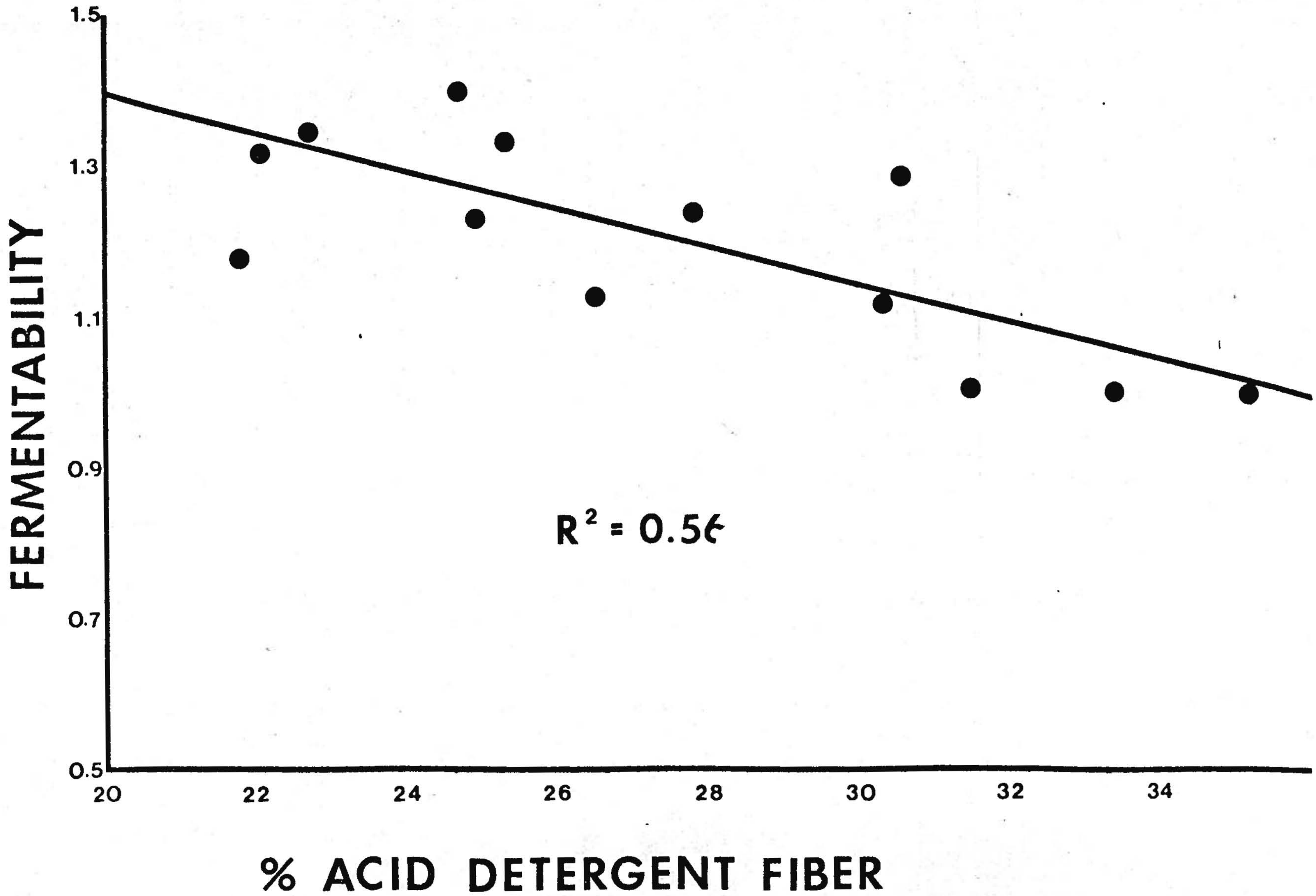
Figure 2. Relationship Between Soluble Sugars and Acid Detergent Fiber in Almond Hulls




FERMENTABILITY
1.5
1.3
1.1
.90
.70
.50
18
20
22
24
26
28
30
32
% SOLUBLE SUGAR
γ 2 = 0.03
NOT SIGNIFICANTLY DIFFERENT
FROM NO RELATIONSHIP



FERMENTABILITY
1.5
1.3
1.1
0.9
0.7
0.5
12
14
16
18
20
22
24
26
% CRUDE FIBER
R² = 0.02
NOT SIGNIFICANTLY DIFFERENT
FROM NO RELATIONSHIP



1.5
1.3
1.1
0.9
0.7
0.5
FERMENTABILITY
R² = 0.56
20
22
24
26
28
30
32
34
% ACID DETERGENT FIBER