6. Application of Pesticide Granules to Soil

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ENGINEERING PROBLEMS ASSOCIATED WITH GRANULE APPLICATION IN ROW CROPS

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INTRODUCTION

As all agrochemical companies know well, the costs of developing a product from initial discovery to commercial field use are extremely high. The process can also take many years to achieve. However, the product can only be biologically effective if placed on the target, in the right quantity, at the right time.

These application considerations are often left right until the commercial launch, or new crop registration. Very little consideration is given to application methods and field conditions during development.

The objective of the engineer is to apply the chemical safely and accurately, where recommended by the chemical manufacturer and to meet local cultural, health and safety conditions.

Equipment may, or may not exist to do the job. The formulation may not be suitable for existing application equipment. Local field conditions and cultural practices have a great effect on choice of application methods. Operator and environmental safety must come first.

Manufacturers of application equipment are often left with very little time to design or adapt units to suit the needs of the chemical companies, once a chemical is launched, machines are needed quickly.

In developed agriculture, conditions are usually well defined, farming is mechanised, and use or adaptation of existing granule application equipment is possible. This is not always the case in under-developed agriculture.

MACHINE SPECIFICATIONS - DEVELOPED AGRICULTURE

Any piece of apparatus for measuring and distributing granules can be considered a machine. These vary from sophisticated positive displacement metering systems to a simple plastic spoon of 20 milligrammes as is used to apply granules to cotton in China. So here comes the first problem - what kind of machine, and how does it fit the carrier?

Consider a mechanised system in the U.K., for example. The granule applicator is usually carried on a seeder or toolbar. One of our biggest problems is to develop, and have available, brackets to fit a multitude of toolbar profiles and sizes. Some twenty years ago when granular pesticides were in their infancy farmers and distributors were prepared to fabricate their own mounting brackets. Nowadays it all has to come as a ready made, bolt-on package. Nobody has the time, or money, to do the adaptation work which was carried out willingly in the past. Inevitably this leads to higher manufacturing costs due to small runs of specific brackets and other fittings.

Having mounted the machine we then need to drive it. Usually three systems are available - electric, hydraulic and landwheel. Without a doubt the landwheel system is the best. It is no good having a precise metering system if the application rate alters due to variation in forward speed of the machine. Driver error, another variable, creeps in. With a landwheel drive, application is always constant.

A remote landwheel is the simplest way but many machines utilise a direct drive from the seeder. More problems in designing individual drives from different input sources. It is very desirable to maintain a common calibration input speed in the interests of standardised published calibration information, so special drives are needed to convert different seeder input speeds to this standard. Confusion is often created by "do it yourself" drives built by users, which do not conform to standard calibration charts.

Also, problems apply with seeder tubes. The part which actually places the chemical. Some chemicals need to be with the seed, some alongside the seed, under the seed, over the seed, mixed with soil - and so the list goes on. Over the years we have developed a whole armoury of tubes and fishtail spreaders for different applications.

Some seeder manufacturers seem to go out of their way to make fitting a seeder tube a work of art. The target area is filled with seed wheels, scrapers, coverers, depth wheels and linkages, which often mean that the seeder tube has to weave its way through these parts to reach the target. Remember, that we need precise positioning of the chemical. With some products an error of a few millimetres can be the difference between a job well done, or crop failure due to pest attack or phytotoxicity.

I would like to add, however, that there are a few enlightened seeder manufacturers who make provision for fitting seeder tubes for granule application, which makes our job a lot simpler.

Now to connect the metering system to the seeder tube. What would seem to need a simple piece of plastic piping turns out to be more complicated. When the toolbar is lifted on the tractor 3-point linkage some seeder units drop by about half a metre. Consequently a fixed length tube becomes detatched and telescopic tubes must be used to ensure correct operation.

Finally, on seeders. We have a suitable range of applicators, mountings, drives and seeder tubes, all we need - and then somebody invents the folding seeder. Normally 12 rows and upwards with two wings which fold vertically at the sides for road transport. Now hopper lids have to be granule-tight when tilted horizontally, and drives must be demountable to cater for the folding sections, just another problem for the engineers.

All these points on seeders can easily be addressed by seeder manufacturers who also make granule applicators, as often happens in France, Germany and the U.S.A. for example. But for the specialist manufacturer of granule application equipment, getting the seeder and applicator compatible can be a problem.

APPLICATION PARAMETERS

The chemical company dictates the rate, placement and, in the U.K., the method of application of the granules. The engineer provides the hardware to achieve this. The problem is to get the two together, and then communicate the results to the end user.

It is desirable, therefore, that new products are tested for application suitability very early in their life. A formulation may be dusty, or highly abrasive for example. This requires special designs of metering systems to ensure that no damage is caused to the product or application equipment. Some chemical companies have their own testing systems and some will send samples to application equipment manufacturers. Sometimes design changes are needed to formulation and/or equipment to enable a product to be applied.

Assuming all is well with the product, and the machine's calibrations and application rates must be communicated to the user. What units? Pounds per acre or kilogrammes per hectare? Both dependent on row width and both causing some confusion in the U.K. market. Dual listing is essential. A much better way is to give rates in a linear form. Grammes per hundred metres or ounces per hundred yards. This is not dependent on row width, and has a "feel" to it. The user can run his machine for 100 yards or metres, and measure the product over that distance. He can check his rates easily. Many chemical companies now use this linear notation of application rate and life has become easier as a result.

One problem for the application machinery manufacturer is, who supplies the rates to the customer? He is supposed to be the expert on his own machine but unless he has tested the chemical himself it is practically impossible to know setting for all chemicals on all crops and what is recommended. However, he is usually the first contact for the farmer and however tactfully you ask the farmer to read the chemical label, he expects you to have the answer yourself.

In the U.K., legislation is very clear on this point. The chemical company dictates the rates and method of application, and to this end labels, instructions for use, and product brochures are well designed to convey this information. However, most problems would be solved in the user applied the old adage "if in doubt, read the instructions", before picking up the telephone. In many countries the responsibility for application data seems to lie with machinery manufacturers and this responsibility is discharged to the best of their abilities, but if they are not in close contact with the chemical companies they cannot have all the information needed and the onus is put on the user to work out his own calibrations, sometimes with disastrous results. Obviously where a chemical company owns, or is aligned to a manufacturer of application equipment the process is simpler for their own products.

UNDER-DEVELOPED AGRICULTURE

I have spent some time on mechanised application systems in developed agriculture and their problems, but these are relatively easy to solve compared with application situations in under-developed agriculture.

Whilst granular pesticides can give tremendous benefit in such situations their safe and accurate application can be very difficult.

Where mechanisation exists, design of machines can basically follow European practice. However, many schemes have failed due to someone just ordering "granule applicators". It is imperative that the engineer sees the operating conditions, normally very different to Europe. In some cases very rough terrain, inexperienced tractor drivers and tractors without any speed indication can destroy a chemical application programme. Additional strength, perhaps four or five times the norm, may need to be built in to ensure the mechanical survival of the equipment. As far as machine design goes simplicity is the key. Motive power can be provided by tractor, horses, mules, oxen or simply manpower. Landwheel drive and positive displacement metering will always give accurate application regardless of forward speed variations.

Temperature, humidity and rainfall affect the performance of chemicals and machines. As most granular products require moisture to activate them, irrigation type and frequency must be taken into account. Cultural practices may need to be changed to enable chemical to be applied. Plantation layout and terrain may dictate the method of application. Costs of application equipment are often a very high consideration. If you design application equipment it may have to compete in price with a spoon or scoop. Although chemical company sponsorship of machines can help in this area. Safety to operators and environment is often difficult to sell. Accuracy of application is a difficult concept to grasp when you have been throwing chemicals about by hand. But, remember the 20 milligramme spoon, savings created by "mechanising" that application were tremendous.

In some situations it is necessary to convert a previous hand application to a mechanised one due to very low rates needed. Some applications to cotton for example are made at 2 to 3 kilogrammes per hectare. Imagine trying to spread two bags of sugar absolutely evenly over a hectare? Many granule applicators will not work at these low rates, but the problem was solved with a precision metering system.

Throughout the world in labour intensive situations, there is a need for simple, accurate and robust hand application equipment. Too many treatments are made using gloved hands and inaccurate scoops and measures. Some crops treated as individual plants may only need one fiftieth of a gramme of product per plant and this is impossible to measure without a machine of some sort.

Chemical companies are becoming more aware of this need, and where knapsack sprayers are now considered the standard tool for liquid spraying by hand, a whole range of hand application equipment already exists, or is being developed to bring safe, accurate granule application to hand operated situations. No single machine will cover most application situations as the knapsack sprayer does, but the development of a range of equipment is a priority. This is the challenge for the engineers.

SUMMARY/CONCLUSION

The problems will always be there to tax our ingenuity, and I hope that we can solve them and live up to the challenge to always apply granular chemicals, safely, accurately and in the right place.

PRACTICAL PROBLEMS IN ACHIEVING RECOMMENDED PLACEMENT OF GRANULES

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ABSTRACT

The practical problems in achieving the directed placement recommended by agrochemical companies for granules applied at row crop drilling are discussed. The difficulties experienced by the machinery manufacturers, and indeed grower, could be prevented by improved liaison between all concerned and a unified approach.

INTRODUCTION

When contemplating the application of the many and varied pesticide granules to the soil, it is the word application we must heed most carefully because engineering solutions have to meet the grower's total application and crop requirements in order to ensure carefully directed placement and efficient utilisation of pesticide granules.

Attaching applicators to field equipment such as direct seeders, transplanters, bed formers, and stone separators, present few problems to the engineer. Indeed, application rates are easy to achieve after due consideration is given to the most efficient forward speed of the carrier machine. However, serious problems can arise in the critical area of placement of the granules. Placement alternatives suggested by the pesticide suppliers have reduced in recent years, but recommendations still fall into 5 distinct areas. New drills can incorporate design features to assist the application of pesticide granules. On the new Rallye 590 seed drill from Stanhay Webb, every metering unit casting has an integral opening for positive location of placement attachments. When applicators are attached to seed drills of old or indeed current design, achieving the recommended placement is far from straightforward. As a leading manufacturer of precision seeders and applicators, we make a plea for closer liaison with agrochemical companies.

At present it appears to us as machinery manufacturers that someone, somewhere, determines where pesticide granules need to be placed with little consideration given to the practical problems involved. This leaves the equipment manufacturers, and the end user, - that all important customer - to sort out any problems.

GROWER REQUIREMENTS

Stanhay Webb's experience is that we supply 95% of our applicators on direct seeders where the pesticide granules are placed in the seed furrow or in bands near the seed. Applicators are tailormade to fit direct seeders and are extremely safe and cost effective. Attachment to transplanters is not popular due to the fact that operatives sit in close proximity to the pesticide granules and also to the drive mechanism of the applicator. The extra cost incurred to fit applicators to the front of tractors and to other items of farm machinery usually deters all but the very specialist grower. Safety and cost are much less of a problem when applicators are mounted on direct seeding drills with one man operation from the tractor cab.

Consider also that growers rarely have a specific seed drill for specific crops and versatility is still a key factor, influencing machinery sales. One drill therefore, may be handling seeds of a whole range of crops. Each crop has different pest problems, and consequently application rates and placement positions vary. Seed drills are now also carrying applicators for soil conditioner placement, herbicide band spray systems, and even attachments such as soil or clod deflectors to create the ideal mini-seed bed environment. These all add to the engineering problems of placement of the pesticide, if only because of the limited space available. One further aspect influencing placement, is seed bed conditions and these vary more than ever, not only from season to season with drilling taking place ten months of the year, but also ideas on optimum preparation techniques change. For example, growers no longer accept that a finely cultivated and rolled seed bed is best.

GRANULE PLACEMENT POSITION

The main five placement areas currently in use are as follows:

1. Forward of the seed drill.
2. Forward of the coulter on the seed drill.
3. In the seed furrow with the seed.
4. In with the soil covering the seed.
5. In with the soil in secondary soil covering.

General comments relating to findings when each of the above methods are applied are as follows.

1. Forward of the seed drill. This position is recommended to give good incorporation of the granules in the soil. However, although the front wheel of the drill is normally scraped clean, granules stick periodically to its surface, and this results in irregular incorporation which is barely compensated by high application rates.

1A. Forward of the seed drill with soil deflector fitted. Attachment of the tube in this instance is to the blade of the deflector with a fixed bracket. As the blade itself has a floating action, soil blockages and granule drift can occur, as well as granules sticking to the front wheel of the drill, resulting in irregular incorporation.

2. Forward of the coulter on the seed drill. This position is recommended on the assumption that a good soil mix occurs with soil disturbed by the coulter splitting granules and providing an initial mix. This soil, moved to either side of the following seed furrow, is then 're-mixed' by the soil coverers attached to seed drills. Considering that seed drills can have one or two coverers of different shapes and sizes, and that many drills are not fitted with a coverer, benefits from this placement position remain questionable. Furthermore, from an engineering viewpoint, the confined space available makes this the most difficult placement position to accommodate efficiently.

3. In the seed furrow with the seed. This is generally the most common recommendation, and attachment of placement spouts in this position is standardised. It must not be overlooked that seed drills may have a small seed press wheel following immediately behind the seed with the purpose of firming the seed into moisture in the furrow. This wheel, however, will also be coming into contact with pesticide granules and may

indeed move or pick up granules in moist conditions, which are of course prevalant in the United Kingdom. Furthermore, seeds drilled deeper than 25mm necessitate placement spouts being designed to overcome soil blockage.

4. In with the soil covering the seed. This is the simplest to engineer and possibly the most consistently effective position, provided that possible soil blockage problems are overcome.

5. In with the soil in secondary soil covering. This is an excellent idea, but necessitates extending the seed drill chassis and adding a second soil coverer, with considerable extra expense for the grower, and is therefore not popular. However this position is potentially very accurate, effective and easy to engineer.

FLOW CHARACTERISTICS

Flow characteristics of the granules can ease engineering problems, but free flowing granules are rare, and low rates of application, 3g/10m for example, do not encourage even flow. Selection of the outlet tube guiding granules from the metering mechanism to placement is of major importance and the angle of fall is critical when considering the alternative row width settings for various seeds. After accurately metering the granules, no grower wishes to see a fold or crease in the down tube causing a blockage, or stalling the granule flow. In addition, the atmospheric and soil conditions, at the times of day when drilling of seed takes place, which are both extremely variable, also influence the flow of granules down a delivery tube. Furthermore, certain pesticide granule coatings can gradually build on the surface of any down tube, again causing irregular flow. Field experience has proven that a light, smooth-sided plastic tube with telescopic action is most satisfactory for general application. Also, the location of the outlet spout must be such as to minimise the chances of blockage with damp soil, consistent with achieving placement of granules at the desired spot.

CONCLUSION

Our customers would approve strongly if all pesticide granules for application of sowing, were free flowing, had a common rate of application and one standard placement position. As specialists ourselves, we do enjoy the challenges in providing our growers with solutions to the problems of both careful placement and efficient utilisation of pesticide granules to the soil. However, growers are now demanding the most cost effective methods of operating a pest control programme and will not accept any extra cost without guaranteed extra benefits. With this in mind all parties involved must show a greater awareness of the requirements of the market place and increase liaison activity.

DEVELOPMENT OF A COMMERCIAL VERTICAL BAND APPLICATOR

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ABSTRACT

After development during the 1970's and 80's, the concept of deep placement of insecticide granules is now a practical proposition for the vegetable grower. Robust machines can be built to suit a wide range of growing systems. With its obvious advantages, the vertical band technique could and should be adopted more widely.

INTRODUCTION

During the 1970's, Dr Whitehead and his team at Rothamsted Experimental Station worked for many years to produce a machine that achieved sub-surface placement of insecticide granules in a vertical band and prove the superiority of the technique over conventional methods. Their efforts culminated in 1979 with the National Research and Development Council inventions leaflet describing the Vertical Band Applicator and offering manufacturing rights to interested companies. Hence my company's awareness of the VERBA and its potential. Our manufacturing licence was granted in 1982.

DEVELOPMENT OF A COMMERCIAL MACHINE

It is of great credit to the Rothamsted design that the injection boots are totally unaltered. However, the injection boots and the air fan are the only parts that remain from the original design.

When the licence was granted, we immediately commenced building a pre-production machine incorporating our own granule metering mechanism. Its stainless steel rotor offered good resistance to wear and corrosion, and could be machined to close tolerances. Furthermore, our own system of a sliding segment of rotor adjusted using feeler gauges offered advantages in the vital area of calibration over the simple rigid metering wheel (similar to a corn drill) on the NRDC machine.

However, it quickly became clear that multi-rotor units would be required. This immediately presented problems since clearly anything with more than two outlets could not be calibrated without emptying out the granules for access through the hopper. Engineering evolution led to the MK85 rotor which is virtually the present day state of the finished product.

The MK85 rotor was designed in 1984, incorporated on our conventional applicators, and adapted to multi-unit rotors for the Verba with up to twelve outlets in series on a single shaft. Combining large numbers of rotors in itself created calibration problems. An external screw vernier system was designed and built in an attempt to guarantee accuracy over the whole length of a multiple shaft on which twenty-four moving parts all contribute to error and tolerances. The prototype and first production verniers worked well and the problems appeared to be overcome. Then one machine completed 1200 acres in a year applying a sand based granule. Sand dust working on the rotating vernier locking bush wore 3mm from the bearing which represented a 100% error on the 3mm gap in the rotor that was required to obtain the correct output.

This merely serves to illustrate how the process of development can be lengthy and frustrating with each error or under design taking one year to expose and then a second year to test the solution. However, we now have evolved a tried, tested and proven metering mechanism capable of withstanding the most strenuous use.

PRESENT DAY FLEXIBILITY

Early versions were adequate for narrow working width (2m) on cultivated land but farmers will always want to do things faster and deeper and wider than their neighbours. As working widths increased for 3 to 3.5m farming or bed systems, chassis strength had to increase to match with 50mm hollow section replacing 24mm square bar. More recently in 1986 and 1987 three 6m wide machines, based on a chassis of 100mm box section and with 6" wide depth wheels, have achieved at least 1000 acres each per year; one doing approximately 1600 acres. (It should be noted that most ploughs will only do 1600 acres in their useful lifetime.)

Over the years of development, we have progressed from a very small prototype to a position where we can build a Verba to suit a 1m bed system, 60" or 72" beds, or 3m or 4m cultivators. All these options can be front or rear mounted. They may be used in conjunction with a drill, or for injecting granules between growing crop rows, or to place a band to be cultivated and mixed into the soil to give overall coverage.

After this hard, frustrating and expensive development, we have the ability to build Verbas for 1 to 6m working width that will dose accurately and consistently from 4 up to 40kg per hectare in infinitely variable steps. The granule base does not wear out the rotor or brushes in the metering mechanism in one season; the frame and wheels are robust enough to survive the most arduous conditions. High seasonal work loads have given a severe test to the machine and proven it to be fit for the purpose.

Future planning and developments are not likely to require any Verbas wider than 6m, but without doubt there will be an ever-increasing diversity of configuration required which we are well able to build.

DISCUSSION

"The dependence of the planned production of high quality field vegetables in the UK upon synthetic pesticides is irrefutable. However, increasing public concern over contamination of food and the environment at large has made the development of more efficient practical methods of insecticide usage a necessity". (A. R. Thompson, 1987).

The superior protective effect of deep placement of chemicals compared to surface distribution was appreciated as early as 1967, some 20 years before this statement was made. Yet, despite the availability of a practical method of attaining deep placement, the vast majority of granular insecticide users persist with surface distribution. Whilst the inefficiency of surface placement may be accepted commercially, the potential to reduce the exposure of the environment to chemicals should not be missed. Why has sub-surface placement not been adopted more widely?

Undoubtedly one reason is the impatience of the would-be purchaser. Each machine has to be designed and built as a "one-off", uniquely tailored to the system each grower uses. Few customers are prepared to accept that this process takes time, order early enough and then cope with the teething problems. When disappointed they persist with their traditional techniques.

However, the chemical industry must help if it is not to risk being accused of complacency. If sub-surface vertical band application of insecticide granules is right for efficient vegetable production and for the environment, then the industry as a whole must collaborate towards that end. If there is not sufficient benefit to make it worthwhile, then let us face that fact and devote our time to other more useful matters.

REFERENCES

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A HAND-HELD PRECISION SPOT-APPLICATOR FOR GRANULAR INSECTICIDES

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ABSTRACT

A rugged, inexpensive, precision spot-applicator has been developed with an integral design of chemical pack that eliminates operator contact with the granule product. The applicator and its design concepts are described as developed for use in transplanted tobacco in Zimbabwe. The system appears suitable for wider use in poorer farming communities where hazardous materials such as ethoprophos, thiofanox and aldicarb are in use as granular spot-treatments.

INTRODUCTION

Many residual insecticides used in the tropics for the control of sucking pests possess relatively high mammalian toxicity. To keep production costs down, and for reasons of safety, these materials are often presented as granule formulations which require appropriate application equipment.

Granule applicators are generally available for use on estates and mechanised farming areas although this equipment is often expensive. For poorer areas however, especially where small-scale hand-held equipment is needed, the options are usually too flimsy, inaccurate, costly, or simply nonexistent. This usually results in the dangerous practice of applying granules by hand without proper protective measures.

The international FAO Code of Conduct requires that suitable means of applying pesticides should be made available to ensure that operators do not come into contact with the chemicals they are applying. As part of a global response to this directive, inexpensive hand-held applicators are being designed for the use of materials such as thiofanox, ethoprophos and aldicarb. This paper describes one such applicator, together with a suitable chemical pack, developed for use of DACAMOX 5G (4.6% thiofanox) in transplanted tobacco in Zimbabwe.

TRADITIONAL USE OF INSECTICIDE GRANULES DURING TOBACCO PLANTING IN ZIMBABWE

Thiofanox is recommended for use against aphid and red-spider infestations in transplanted tobacco. The planting of this crop in Zimbabwe and the traditional use of insecticide granules requires some description to understand the requirements for a hand-held spot-applicator.

Planting stations are first holed-out in ridges at regular intervals (either mechanically or by hand-hoe). Insecticide granules are then placed in each planting hole and under dry conditions water may be added as well. The tobacco transplants are then planted in the hole and firmed-in.

The insecticide granules are usually applied by hand, often by a woman carrying a child. The granules are roughly measured into a measuring cup or spoon by plunging the measure into a bucket of the granules. This quantity is then dropped or scattered into the planting hole.

In the case of toxic granules, packs carry a purple label with skull & crossbones and the warning, "Very dangerous poison, extremely harmful by skin absorption". Precautions to wear full protective clothing (rubber gloves, rubber boots, overalls and a respirator) are also stated. Such precautions however are either ignored completely; followed for a short period until temperatures become too uncomfortable; or partly followed, with the employer only supplying some of the protective clothing.

Skin contact with the granules is continuous and in temperatures of 20 to 30°C, moist sweat on the skin increases the hazard. Nausea, giddiness and headache are common amongst workers handling the chemical. Apart from the obvious health risks, there are also economic consequences of this misuse. The job is unpopular and therefore often carried out in a wasteful, sloppy fashion. It has been known for poorly supervised gangs to purposely miss whole areas of crop and bury the unused chemical to escape exposure to it.

APPLICATOR AND CHEMICAL PACK DESIGN

The concepts behind the construction of a suitable applicator and pack system, refined by in-depth field testing at over 20 sites in Zimbabwe during 1986, are discussed below.

Cost

The applicator needed to be inexpensive to permit use by farmers in poorer areas, particularly in developing countries. To be inexpensive meant that the applicator had to be manufactured locally in the territory where it was to be used. This was to avoid unnecessary labour costs, shipping charges and import duties on finished units. Local manufacture demanded a simple design, incorporating readily available materials which could be assembled by unskilled staff using basic techniques with a minimum of workshop facilities.

The same provisos held for the chemical pack to be used to supply the applicator. Local manufacturing and packaging of granule products had to use locally available materials and technology.

Safety

To prevent the operator coming into contact with the product it was necessary to adopt a ready-to-use pack and a fool-proof method of connecting the pack to the applicator. All pouring of granules, emptying and refilling, were to be eliminated. The combined pack plus applicator needed to be leak-proof, especially against any dust derived from the granule. When empty, the pack itself must not be reusable as receptacle for food, drink, as a toy or for any other use. The system described would also mean that protective clothing (always hated in the tropics) would be largely unnecessary.

Ease of use

The applicator had to permit prolonged use under tropical conditions without excessive operator fatigue. This required that the weight of granules to be applied should be taken on the back (a maximum of 15 kg) and not held in the arms. Accordingly, a suitable hose connection was required between the back-pack and the applicator and which could also take some of the weight of the applicator itself. The applicator should be held by the operator in a naturally relaxed position without stooping, permitting several hours of continuous work. The final format of the applicator depended on the metering system to be used.

Granule metering method

Various hand-held spot-applicators had been tested but all were found to be unsuitable for a variety of reasons. Applicators relying solely on gravity flow tended to be slow and some required excessive arm movement (up to 180 degrees rotation) to effect delivery. Other types using spring-loaded buttons or plungers proved tiring and frequently jammed when using coarse granules. Trigger-operated systems, besides fatiguing the hand or fingers, usually incorporated a valve based on sliding cones, slieves or blocks which required a relatively complex sprung-lever mechanism, either expensive or difficult to fabricate with basic facilities.

A "rotary valve" system proved the best solution as this permitted construction of an applicator with only one moving part. Details of the metering assembly are shown in Figure 1. A metering disc, with an orifice drilled to a given diameter, was keyed onto a spindle and rotated against a fixed block which carried the inlet port (the block also served as a bearing for the spindle). Beneath the metering disc, and holding the disc against the inlet block (using a spring located at the end of the spindle) was a second block. This block (also serving as a guard-piece) carried the outlet port which was offset in relation to the inlet port. Reciprocal rotation of the disc between these two positions provided the precise measurement of granules required. This movement was obtained using the operating knob, keyed onto the other end of the spindle, with a maximum rotation of only 90 degrees. With the knob held at a comfortable height for wrist-action operation (approximately waist height with the arm relaxed) this proved to be a satisfactory combination involving little fatigue.

Granule delivery and applicator format

The applicator was required to apply granules within a "spot" of approx. 100 mm diameter. This necessitated release of the granules reasonably close to ground-level to avoid excessive dispersal by wind. Furthermore, it was necessary to place the granule release-point as low as possible to obtain a rapid action. Tubes, fishtails, inclined spouts and similar means of directing granules to the impact point all slowed down granule flow, reducing the effective work rate.

According to the tubular format of the applicator as shown in Figure 1., the metering assembly was housed in the tube-end and supplied by a flexible hose directly to the chemical back-pack. The rest of the tube, above the level of the delivery-pipe, contained no granules but acted as the carrying handle with the operating knob.

By altering the length of tube between the metering assembly and the knob, it also proved feasible to supply applicators of variable length to suit different ground conditions. Tobacco in Zimbabwe is planted on a raised bed and thus requires a slightly shorter applicator for comfort than for example irrigated cotton. With a minimum ridge height of 0.3m and operator height varying between 1.52m and 1.91m, it was found that the ideal length for the machine was 0.98m for use in tobacco planting.

Range of application rate and accuracy

Dose rate had to be flexible to permit the use of a range of granule products or locally-made formulations with different active-ingredient loadings. The range of dose rate required was 0.5 to 2.5 grams per spot, consistent with treating individual plants in a row-crop situation with relatively small quantities of granules. Application was to be reproducible across the range to within ± 5% of the dose intended.

Selection of metering discs and output range

In some areas it is necessary to supply an applicator with a fixed level of output to prevent operators tampering with dose rates. In such cases the applicator can be supplied as a sealed unit.

As an alternative, the applicator can be supplied with a range of metering discs, either stamped or colour-coded, and which may be changed in a few seconds, requiring only a screwdriver.

The metering port(s) in each disc may be drilled typically to any diameter between 5 and 12 mm at intervals of 0.5 mm. Tests with the applicator showed that output of a granule formulation across this range was directly proportional to the orifice diameter.

It also proved feasible to construct a double-acting unit by drilling two holes in the metering disc, thus giving the option of two spots (rather than one) per cycle of the operating knob.

Component materials and durability

The applicator body was made from sections of standard-size PVC drain-pipe which is available in many parts of the world and which provides a tough, durable material. The central spindle was made from aluminium alloy bar onto which was keyed the operating knob and the metering disc. Bearings for the spindle were cut from nylon rod and, after drilling, located in the tube at appropriate positions. The metering disc was also cut from nylon rod, giving good abrasion resistance.

Wear of the metering disc, housing and axle-bearings was observed after treatment of the first few sites whilst using granule formulations based on brick-chip. The wear took the form of deep scoring but did not appear to increase significantly whilst treating further sites. Application rates and ease of operation remained unaffected.

Effects of wear are eventually inevitable in a machine of this type but the parts affected may be replaced easily. Assuming an applicator may be used for 30 days per year at a rate of 1 hectare per day to treat 15,000 planting stations per hectare, it is calculated that over three years a single machine will sustain 1,350,000 cycles of operation, applying upwards of 1.35 tonnes of granule product. Such quantities are rarely associated with the use of hand-held applicators.

Waterproofing

The whole applicator and pack was required to be rainproof to prevent moisture reaching the granules. This was important under tropical conditions where intense rainfall may occur. Solvent welding of the external joints between the plastic parts of the applicator sufficed.

It was also found necessary to guard the end of the applicator to prevent damp soil, or other accidental sources of moisture such as wet foliage, reaching the metering mechanism. This guard was made from the same piece as the outlet block of the metering assembly.

Anti-clogging measures

Most granule applicators tend to grind the formulated granule products to a greater or lesser extent. The result is the production of dusty material which fails to flow properly and accumulates in the working parts which then stiffen or jam and become subject to increased abrasion. Various precautions were taken to prevent this problem.

Firstly, large lateral clearances were allowed between the metering disc and its housing to prevent fines accumulating in excess. Secondly, in the outlet block directly under the metering disc, rows of holes were drilled to permit fines to escape along the same route as the metered granules. Thirdly, the metering disc was held against the inlet block by weak spring pressure against which the whole spindle assembly floated, including the outlet block (guard-piece). In the case of persistent tightening of the mechanism, a smart tap on the operating knob would serve to momentarily loosen the disc and restore normal working. Note that the guard-piece was able to slide up and down against the spring pressure and was kept in place by a locating screw (see Figure 1). The latter also prevented any rotational movement of the guard-piece whilst in contact with the metering disc.

Pack design

Standard, cheap, semi-rigid, plastic "J-Packs" were quite unsuitable as packs for a toxic insecticide in Zimbabwe owing to the risk of subsequent re-use as water or food containers. Thus a novel package was sought that would be non re-usable and disposable after use; robust enough to stack for transport or storage; water-proof for field use in the rainy season; comfortable to wear. Moreover, the pack required a foil barrier to contain any solvent vapour released by the granules during storage. Above all, the pack had to be manufactured, and filled, locally and cheaply. The pack was required to contain one hectare's worth of chemical or some convenient fraction of this quantity.

A collapsible pack based on the "wine-bag" concept was considered the best option. A seam-welded inner bag surrounded by a foil liner was to be used with 30mm excess material left along the upper edge to permit closure by stitching when the bag was filled. This strip would also give support to the bag when hung on the operator's back. A polyweave outer bag encompassed the whole. At one corner of the inner bag was welded a quick-coupler compatible with the tube connecting with the applicator. The pack was to be opened by cutting the outer bag across one corner and extracting the welded outlet whose seal is broken when the hose connection is made.

Once coupled to the applicator, the pack is pierced at one corner by a sharp hook which is in turn attached to a simple harness carried by the operator. Once the bag is pierced in this fashion its re-use as a container is prevented. Suspending the bag by one corner also assists granule flow into the connecting hose.

The connecting tube between the applicator and the pack required a minimum internal diameter of 15mm to avoid bridging of coarse formulations within the tube. It also helped if the tube was of translucent material so that the supply of granules to the applicator could be monitored. Clear plastic tubing proved adequate as long as it was thick-walled to withstand rough treatment and did not become floppy at high temperatures.

SUMMARY

The applicator and pack were tested in the field using DACAMOX to compare with conventional methods of application using standard materials for control of aphid and red-spider mite in transplanted tobacco.

The applicator with its "zero pesticide contact" principle was well received by farmers, extension officers and field workers alike since it avoided both skin and respiratory contamination. Various acclaimed benefits included :-

i) Accuracy and consistency of dosage which was expected to improve biological effect as well as avoiding wastage:
ii) Simplicity of use for unskilled operators:
iii) Faster work rate: It was calculated that one operator could treat one hectare in 3 to 4 hours, 2 to 3 times faster than the traditional methods described earlier:
v) Faster work allowed the number of operators employed on chemical application to be reduced:
vi) The need for protective clothing was removed.

Farmers expressed their interest in trying other insecticide granules through the applicator, as well as fertilizers.

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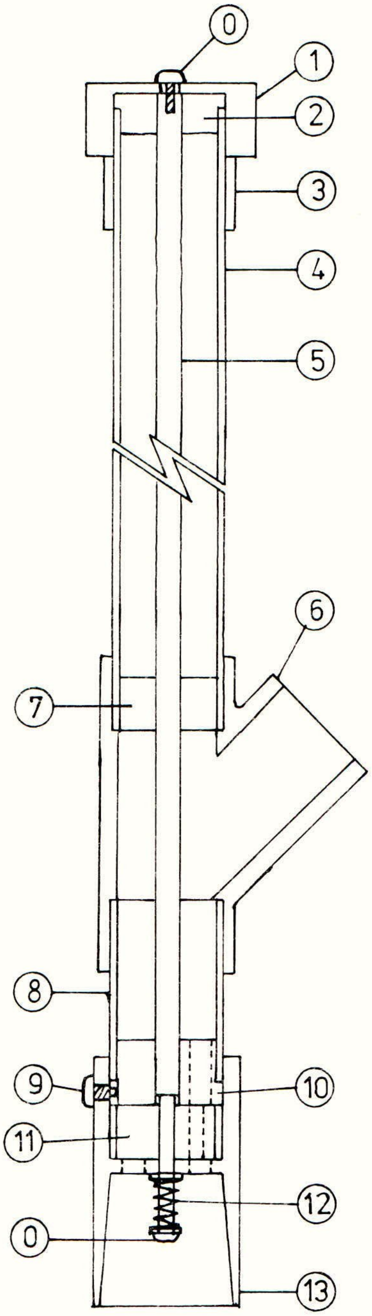
2. Mr P. Wilkinson of May & Baker Zimbabwe Ltd. lent valuable assistance in the initial field-testing and proving of the design under the conditions of local farming practice.

Fig. 1. Diagram of the applicator



Key :-

0. Screw
1. Operator knob
2. Top bearing block
3. Stop ring
4. Long tube (carrying handle)
5. Spindle
6. Y-piece for hose-tail
7. Centre bearing block
8. Short tube
9. Locating screw
10. Bottom bearing block with inlet port
11. Metering disc with variable orifice(s)
12. Spring & washers
13. Guard piece with outlet port(s)