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# Use of the controlled droplet application (c.d.a.) technique for herbicide application

## Basic considerations, equipment, trials and recommendations

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*Considerable savings in expenditure on weed control can be brought about in oil palm and rubber estates by use of the controlled droplet application (c.d.a.) technique, with economies of 50–60 per cent being recorded. Savings apply to costs of herbicide, labour and water transport when compared with the normally-used knapsack sprayers applying 200–600 litres per hectare as against 14–22 l/ha with c.d.a. Some basic considerations of sprays are given to aid understanding of the reason for the suggested change, particularly the importance of droplet size. A description is given of the Micron Herbi equipment used for trials and of adaptations for locally-assembled units using Herbi heads, including a double-headed machine for oil palm circle spraying. Trials were carried out in North Sumatra on rubber fertiliser strips, oil palm paths and circles, removal of grasses in legume, and nursery weed control. Recommendations are given for most situations, predominantly utilising Roundup at 0.5–0.75 litres per sprayed hectare, sometimes with ammonium sulphate additions, with total spray volumes within the range 13.5–22 litres per hectare. Indications of productivity are given, with hourly coverage of 3 km of paths and 1 hectare of mature oil palm circles (at 143 palms per hectare) suggested as targets. Brief consideration is made of other reduced volume techniques, some physical factors affecting c.d.a. observed during trials (weather, herbicide longevity, light, weed flora changes) and the need for further experimentation.*

This paper describes the means by which considerable reductions can be made in routine herbicide weed control costs in most oil palm and rubber estates. Early indications are that similar economies can also be made through the same techniques in other perennial plantation crops, *e.g.* coffee, cocoa and coconut. The trials described below have shown that the savings made relate to the three major cost components of herbicide usage, which are:

- **Chemical cost.** Herbicides are generally expensive, with prices continuing to increase in relation to the costs charged by manufacturers and distributors. Normal spraying methods are such that much of the applied chemical is wasted through failing to be deposited on the weed surface because of drift or through running off the weed onto the soil.
- **Water transport.** Established herbicide application techniques in oil palm and rubber involve sprayers applying 200–600 *l*/ha, whilst current world trends towards improved herbicide usage

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include lower application volumes. It is often the case that the cost of transporting large volumes of water to the field is not unusual for correct cost analysis to show that water transport costs at least equal those of herbicides.

- **Labour cost.** The major effect of having to apply large volumes per unit area is that of a high labour requirement. This poses problems of both cost and, in some cases, labour availability. Using the technique described in this paper, both costs and requirements for labour are greatly reduced through greatly increased productivity.

Weed control through herbicides has been approached much more scientifically in recent years. Most estates still use high–volume knapsack sprayers. Although reasonably good results have been achieved by this method, their design has changed only slightly in a very long time. This design depends on a spray operator manually producing the pressure under which spray liquid is transformed into droplets. However, such droplets cover a very broad size spectrum: the equipment uses large volumes of water: operator fatigue is frequently considerable and the ratio of productivity to work input is low. Recent developments have made the authors consider that knapsack sprayers are now largely outmoded with their continued use, mainly due to failure to adopt a superior technique which has been available for several years.

One aspect of knapsack use encountered has been that of unfortunate resistance to change estate practice by senior estate management. Inflexibility of this nature is costly. This has been experienced in two countries where estate management was sufficiently flexible to investigate an alternative spraying method which was subsequently adopted by both management and labour because of economies of both cost and labour. Due to reductions in herbicide, water transport and labour costs, weed control has been reduced by at least 60 per cent on one oil palm estate in Papua New Guinea and by over 50 per cent in oil palm and rubber estates in North Sumatra. The scale of economies will vary between countries because of differences in the weed control cost components. However, there are clear indications that significant economies can be made in all areas where herbicides are currently applied using knapsack sprayers.

The following sections outline the principles and practice of lower spray volume herbicide application using the controlled droplet application (c.d.a.) technique. Since use of c.d.a. involves a different outlook from that of using knapsack sprayers as the principles of the two spraying techniques contrast so sharply, a small section of this paper has been included, describing some fundamental considerations of sprays, to assist in understanding both the c.d.a. method and subsequent suggestions for its use. The equipment used is described and a summary given of trials carried out in Sumatra, the results of which were used to develop a spray programme. Indications are given of the potential for increased productivity. Finally, there is a discussion of the current situation and possible developments.

## SOME CHARACTERISTICS OF SPRAYS

In comparing spray techniques under

uniform conditions, the efficacy of a herbicide increases with the number of spray droplets deposited on the weed surface. Where deposition depends on gravity, spray droplet diameter is of great significance. Where the particle diameter is too low then the catch on the weed surface will be negligible and such small particles also create problems of spray drift. Conversely, whilst a large spray particle may be easily caught on the weed surface it breaks up into only a small number of droplets so that actual cover of the plant surface is restricted. Large droplets also have the tendency to bounce off any non–absorbent surface which is not smooth (*i.e.* plant surfaces) leading to spray wastage. Tests have shown that a droplet size averaging 250$\mu$ is suitable for weed control.

The design of knapsack sprayers allows liquid pressure, achieved through manual pumping, to produce a spray of droplets. Droplet size analysis, using laser beam techniques, has shown that many drops are either too large or too small for successful compaction on a plant surface. In one analysis of droplet production by a knapsack fan jet (Bals, 1978) only 19.8 per cent of all droplets had a diameter greater than or equal to 100$\mu$, and only 11.2 per cent of droplets were greater than 211$\mu$ in diameter. Therefore, the flat fan produced a large percentage of spray particles susceptible to drift, as well as some which were far too large for successful (efficient) impaction.

The principle of c.d.a. is the production of sprays with a narrow range of droplet sizes, with size appropriate to the target (Matthews, 1977), thus offering considerable advantages over conventional hydraulic nozzles. In this paper only the spinning disc method of achieving c.d.a. has been considered, using a Micron Herbi (Bals, 1975, 1978). Comparing spray droplet production with that of a fan jet mentioned above, the c.d.a. disc produced five times as many droplets per litre as the fan jet, with 91 per cent of these being 100$\mu$ or more in diameter, and 74 per cent greater than 211$\mu$. The c.d.a. disc still had 9 per cent particles with diameters below 100$\mu$ but this was considerably less than the flat fan. The spinning disc which breaks up the spray liquid into droplets by rotary atomisation, thus produces a much narrower droplet spectrum than that created through pressure.

The significance of a relatively restricted and constant droplet, size spectrum lies in the fact that low application rates cannot be successfully achieved without a narrow spectrum. All the recommended herbicide rates currently given on produce labels are those necessary to achieve control with irregular droplet sizes. These dosage rates can be understood when it is realised that they relate to a spray with a droplet spectrum which has a conservative range of 50–500$\mu$ (the actual range is much wider), *i.e.* a dosage variation of 1:1000. If a droplet of 50$\mu$ contains enough chemical to kill a pest, the 500$\mu$ droplet wastes 999$\mu$ units of chemical, thus leaving wasteful residue and environmental contamination. Excellent results have been achieved in many crops with only 5–25 per cent of recommended active ingredient dosage rates with dilution according to the specific droplet size required (Bals, 1978).

Economies through c.d.a. usage are thus brought about by selection of the droplet size most effectively deposited on weeds, with wastage being reduced through:

- The much lower herbicide carrier volume used with c.d.a. reduces the risk of run–off, as well as reducing the amount of water pumped, hauled and sprayed.

- There is a great reduction in the number of very small droplets which cause vapour and particle drift. This also allows herbicide usage in places where knapsack sprayers always pose problems, *e.g.* nurseries.

- Reduced drift and run–off losses, together with better coverage and retention, allow lower dosages of herbicide per unit area to be used.

There have been several published results showing that dosage reductions are possible using c.d.a., especially for translocated herbicides (which are normally more expensive than contact chemicals). This can also be achieved with 10–20 *l* per sprayed hectare, as against 200–600 *l* . In fact, reduction in volume has been shown to increase the efficacy of certain herbicides, e.g. glyphosate (Caseley, Coupland & Simmons, 1976; Turner & Loader, 1978).

## EQUIPMENT

### *The Micron Herbi*

In the trials described below, the machine used was a Micron Herbi, manufactured by Micron Sprayers Ltd, Three Mills, Bromyard, Herefordshire, England. The Micron equipment was used since it was readily available: other equipment incorporating the spinning disc principle and delivering the same spray characteristics would be expected to give similar results. Modifications were made which made it more suitable for most estate operations. The Herbi is designed to produce spray liquid drops of 250$\mu$, achieved through gravity flow of liquid at a predetermined rate onto a precision-made disc spinning at a constant speed of 2 000 r.p.m. A constant rotation speed is obtained by a motor, governed (a feature absent from similar equipment) to enable power supply to drop from 12v to 2.5v before motor speed starts dropping, at which point droplets become large and visible.

The standard Herbi is powered by eight ordinary 1.5v batteries to last 80–120 hours. Battery cost is negligible compared with other spraying components; and rechargeable batteries can be used.

Spray containers hold 2.5 *l* ; the small amount is a drawback for most estate-scale operations, thus leading to one of the proposed design changes described below. In theory, spray liquid flows through a nozzle onto the spinning disc at a rate of one ml/sec with a gentle walking speed of one m/sec and an invariable swath width of 1.2 m, giving an application rate of 8.3 *l* per sprayed hectare. In practice, rates are somewhat higher, so that calibration prior to spraying is an essential part of spray practice for different formulations to determine precisely the amounts of chemical and spray applied. Spray nozzles are fitted to the Herbi according to the characteristics of the spray solution to obtain the required flow rate onto the spinning disc of about one ml/sec. A larger nozzle can be used to apply greater amounts per unit area but this affects the process of droplet formation, giving a broader spectrum of droplet size. Swath width is 1.2 m and is hardly affected by usually –

encountered wind speeds of up to 8 kph and especially by wind speeds within mature plantations. It remains at 1.2 m irrespective of height: 1.2 m is ideal for many standard operations, and special adaptations have been constructed for situations requiring a wider swath.

The Herbi is basically a simple machine but has also been designed to be both robust and inexpensive, with the cost of machine and spare parts being negligible when compared with savings; there should be little difference from the cost of ordinary knapsack sprayers. The machine is sufficiently robust to withstand knocks, and repairs are normally easily done. Given proper usage, care and normal maintenance, problems should be few, easily solved through a service manual.

Most herbicide amounts per unit area can be reduced by at least half the normally recommended rate through use of a Herbi spinning disc. Using urea or ammonium sulphate additives, further rate reductions may be possible, and other additives (*e.g.* oil or sticking adjuvant) could prove beneficial. The extent of reduction depends on the types of vegetation to be directed at together with local experimentation. The Herbi works well with contact herbicides at half the normal rate per unit area although best results were obtained with translocated herbicides, with particularly effective results being obtained with glyphosate (Roundup).

Use of a Herbi is straightforward, requiring the observation of a simple set of rules. These require selection of the correct nozzle, proper use of the machine during starting, stopping and the angle of the spray head, calculating rates of spray application and correct preparation of spray solution (which includes a simple calibration method) and routine machine maintenance. A fundamental requirement is, however, that both staff and operators are properly introduced to the technique, which is basically simple and easy, but which requires attention to detail from the outset.

*Modification for estate usage*

During the trials it became evident that modifications were required to the Herbi to maximise the benefit of c.d.a. of herbicides. The standard Herbi would be useful for comparatively few purposes only, *e.g.* nursery spraying, because of the size of the spray container. On the other hand, swath width was ideal for paths, rubber fertiliser strips and circles in young plantings. Therefore, for almost uninterrupted spraying, knapsack spray tanks were converted. This varied according to construction and necessitated by-passing internal pressure pump systems in some instances. Alternatively, used 5-litre herbicide containers, fixed to the spray lance, could be used. Existing or new outlets from tank bottoms were used, ensuring that these were properly sealed since any leakage would be of concentrated chemical. Flow rate analysis showed that slight variations which occurred were acceptable in relation to the considerable additional advantages presented by the larger spray reservoirs.

An alternative spray lance uses aluminium tubing (about 1.5 cm diameter and 1.5–1.7 m long, the length depending on carrier position preference). Holes to take a spray head or other adaptations should be drilled before any wiring is attempted. Fitting the Herbi spinning disc head requires removal of the brass contact plate (the positive connection to the motor) to avoid distortion of the plastic head moulding. For power supply, a 12v motorcycle battery can be used. Whilst this has sufficient power capacity for two weeks running, battery life will be prolonged if it is recharged weekly. More recent indications are that 1.5v batteries may be better. Practical experience was that the power source was best carried mounted towards the back of the spray lance since other positions *e.g.* attached to a belt, caused trouble with trailing wires. Small crocodile clips can be used to attach the differently–coloured positive and negative wiring, which is threaded down through the tube, but all wiring and connections must be readily accessible.

The liquid feed–tube is fixed to the outside of the aluminium tubing so that flow is visible. It is suggested that only high quality imported tubing is used. An on–off tap could be fitted to the lance at a level which is in level with or lower than the tank outlet. If speedy tank change is required, the outlet hose should have a quick release connection. We strongly recommend that only genuine Micron Herbi heads are used. Undoubtedly locally–made substitutes will appear but these should not even be considered until a full range of tests, including those of droplet spectrum and motor reliability, have been carried out. The price of a head is very modest, so cheaper substitutes which could result in enormous losses, are simply not worth considering.

From the above description it can be seen that a very suitable spraying machine *(Figure 1)*, can be easily assembled locally. Only a few components need to be imported and these are

*Figure 1. Prototype of a locally-made sprayer with a 'Herbi' head and 'Solo' tank. The liquid on-off switch in this model is too high and the operator not properly protected. Note the angle of the spray head.*

so small and light as to be rapidly obtainable by air freight if not held by local agents. It is, of course, also possible to import the Herbi without the spray bottle holder assembly and use a knapsack sprayer tank, with power from either motorcycle or flash-light batteries. For initial introduction of the technique, use of standard Herbi Machines could be considered.

*Double–headed adaptation*

For oil palm circles, selective spraying of legumes, field edges and roadsides, *etc*, twice the normal swath width of 1.2 m is needed, together with the larger spray reservoir. Construction of a suitable machine is again simple, and is just an adaptation of the locally-constructed model described previously. Folding arms (0.55 m long) are fitted to the end of the lance, although folding is not an essential feature. To these short (5cm), forwardly–directed (90°) extension, pieces are fitted to allow the spray head angle to be altered. Heads are fitted as for a single–headed machine, and the spray liquid feed tube has to be extended from a T–piece connector to each using identical lengths of tubing. Sufficient wire should be incorporated to allow folding of the sprayer arms. The simple construction detail is given in *Figure 2* and an illustration of a simple adaptation of a standard Herbi machine is shown in *Figure 3*.

TRIALS

Existing weed control techniques, which predominantly utilised knapsack sprayers, were compared with c.d.a. through Micron Herbi heads in a series of field trials on estates in North Sumatra. Particular attention was paid to the necessity for any innovation to be readily incorporated into normal

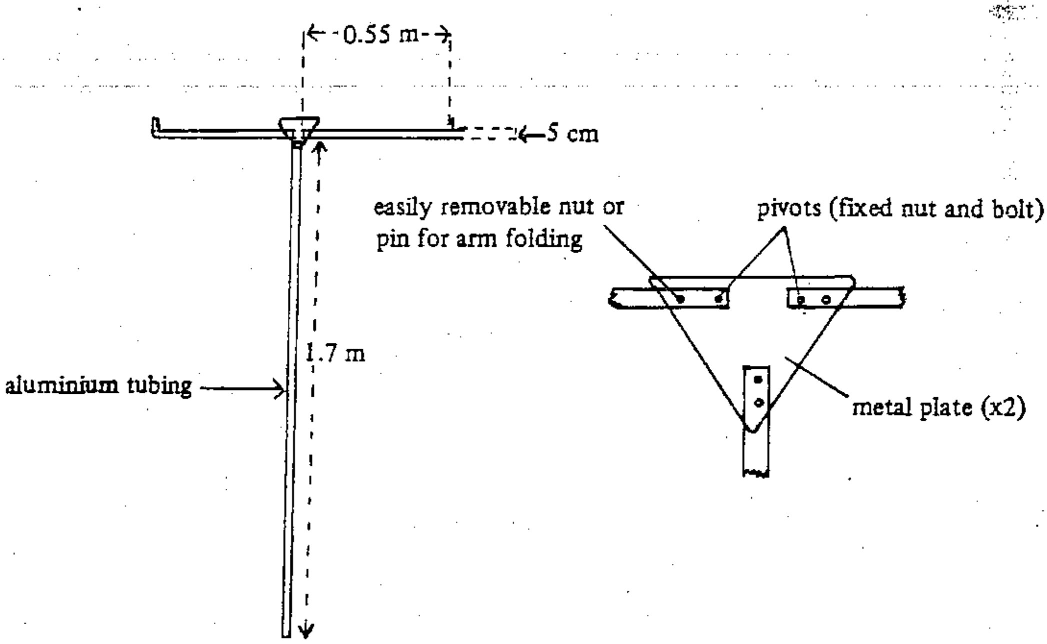


*Figure 2. Method of constructing a double–headed 'Herbi'.*

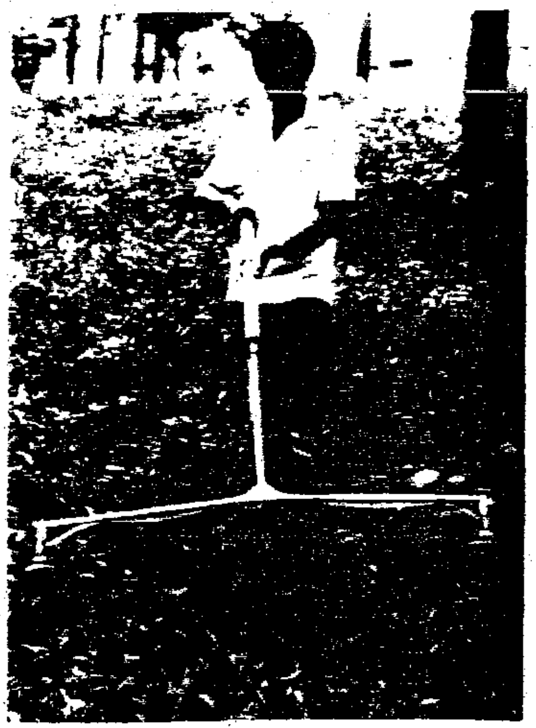

*Figure 3. A prototype double-headed 'Herbi', still incorporating the standard shaft but still could be adapted as in Figure 1.*

estate routine maintenance programmes. The main areas of estate upkeep investigated were, nurseries (in this case, coconut) paths and circle weeding in oil palms, strip weeding in rubber prior to fertiliser application, and grass eradication from legume areas in both crops. Herbicides used were paraquat (as Gramoxone), 2,4–D amine, diuron (in conjunction with paraquat in Paracol), glyphosate (as Roundup) and fluazifop butyl (Fusilade, for grasses in legume), either alone or in combination. Each was applied using the Micron Herbi, with both the blue and yellow nozzles being tested. Comparison was with a knapsack sprayer, either a Solo 425 or Union brand, fitted with a red or blue Polijet nozzle. Adaptations to the standard Herbi machine were made as described above to give the required swath width for oil palm circles and legume grass spraying as well as to give improved work outputs using larger spray tanks.

Each trial involved comparison of different herbicide and volume application rates, with some additional assessment of spray additives. In all trials a species assessment was made both before and after spray applications, with standard recording procedures used in weed regeneration assessments. Dominant weed species in all trial areas were *Paspalum conjugatum, Ottochloa nodosa, Brachiaria mutica, Axonopus compressus* and *Cynodon dactylon,* following a prolonged period of herbicide usage.

For rubber, the plot size was 2.4 x 20 m, obtained by spraying at 1.2 m swath on each side of the row, with three replicates for each treatment. A mixture of paraquat and 2,4–D amine was applied at normal, one-third and one-sixth of normally applied rates at total application volumes of 13.6 and 24.8 *l*/ha with the Herbi sprayer.

For rubber strips, two approaches were tried. In one approach, the common practice of spraying both up and down the row, *i.e.* a 1.2 m strip on either side of the row, was used. In the second approach, a single pass only was made, *(Figure 4).* This relies on the circular (forward and backward) swath of the Herbi to give complete cover around the tree. This was found successful, and it was not necessary either to move the sprayer head around each side of the tree or to make a double pass along the row.

For oil palm circle weeding, the double–headed machine was used, with

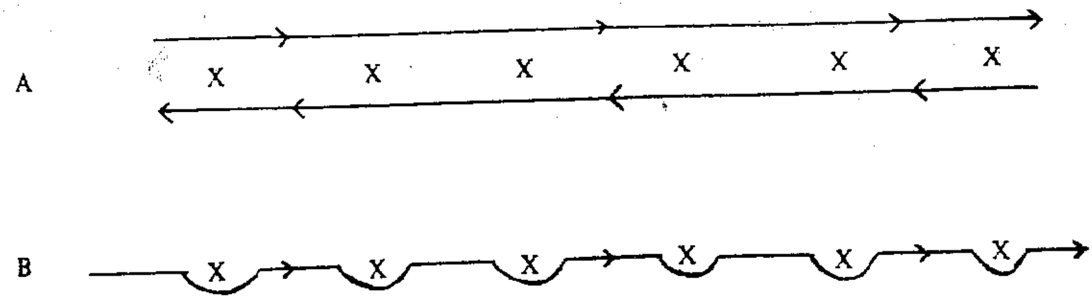


*Figure 4. Spraying techniques for rubber strips. A = double passage of sprayer to produce strips 1.2m wide. B = single (successful) pass with a Herbi which weeds both between and around trees.*

different nozzle combinations used, to take into account the different areas which needed to be covered by each head when spraying the circle. Calculations showed that, assuming the operator walks around the middle of the circle, the inner head covers an area of 8.3$m^2$ and the outer head an area of 17.3 $m^2$ Initial trials used a yellow nozzle on each head applying a total volume of 26 *l*/ha but later trials used a blue nozzle on the inner head, and a yellow nozzle on each outer head, applying a mean volume of 20 *l*/ha. Each plot comprised a 2 m radius circle around a palm, with five replicates per treatment. A mixture of paraquat + 2,4–D amine was applied at full, half and one–quarter normally-applied rates, and glyphosate was applied at 0.9, 0.4 and 0.2 kg a.i./ha, with additions of Ethokem T25 (a surfactant supplied by Midkem, Northampton, England) or ammonium sulphate. Plot size for harvesting paths was 1.2 x 20 m, with three replicates per treatment. Paths in young oil palm in which the canopy had yet to close were sprayed using a standard Herbi machine and knapsack sprayer.

It should be noted that most oil palm trials were carried out in areas where weed control was normally difficult because of ground conditions and the considerable amount of light penetrating the canopy. This particularly applied to trials on oil palm circles, which were very overgrown when sprayed and would have been well past the normal treatment period. Therefore, under normal situations and in easier conditions *e.g.* under closed canopies, even better results would be expected.

For grasses in both oil palm and legume immature stage covers, trials were carried out using Fuilade through a double–headed Herbi at 1–2 *l*/ha, as against the recommended 2–4 *l*/ha.

Only a coconut nursery was available for a trial on nursery ground weed control, with bare ground conditions being preferred. Here Paracol and Roundup were used, using a blue nozzle in a standard Herbi, with the range of Paracol being 0.65–2.4 *l*/ha and for Roundup 0.45–2.25 *l*/ha. There was no comparison made with a knapsack sprayer since even when hooded it is considered that spray drift dangers are too great *(Figure 5)*.

Flow rates of all solutions used in the Micron Herbi were measured *(Table 1)*, as were those of the knapsack sprayers. All trials were arranged in complete randomised block designs.

*Figure 5. Nursery Spraying using a normal 'Herbi'. Note the height and horizontal plane of the spray head.*

TABLE 1. FLOW RATES* OF HERBICIDE SOLUTIONS (ML/MIN) THROUGH THE MICRON HERBI

| *Herbicide* | *Nozzle* | |
|---|---|---|
| | *blue* | *yellow* |
| Paraquat + diuron | 78 | 160 |
| Paraquat + 4–D amine | 99 | 180 |
| Glyphosate | 90 | 170 |
| Fluazifop–butyl | 100 | 170 |

*Means of several measurements under field conditions. Apply ± 5 per cent to all concentrations of herbicides used and ± additives).

Assessments of all blocks for comparison were by visual rating at 20, 40, 60, 90 and 120 days after treatment (DAT) on a scale of 0–10, where 0 = no control and 10 = complete control.

Assuming the basic requirement is that surfaces do not need to be totally weed–free but that passage along paths must be easy and oil palm circles sufficiently clean for easy collection of loose fruit, re–spray is required when the mean score is about 5.

## RESULTS

A summary of the main results is given in *Tables 2* and *3*. These, together with many more observations, have provided the data on which initial herbicide usage rates were decided and which have been introduced on a large scale.

*Strip weeding rubber.*

Where comparisons were made between existing knapsack application techniques and the Herbi using the normally–used herbicide combination of Gramoxone + 2,4–D amine, similar commercially acceptable results were

TABLE 2. STRIP WEEDING RUBBER: MEAN WEED CONTROL ASSESSMENTS (64 DAT) FOR PARAQUAT + 2,4-D AMINE AND GLYPHOSATE

| *Chemical (kg a.i./ha)* | | *Knapsack (blue polijet) 250 l/ha* | *Herbi (yellow nozzle) 24.8 l/ha* | *Herbi (blue nozzle) 13.6 l/ha* |
|---|---|---|---|---|
| *paraquat* | *2,4–D amine* | | | |
| 0.36* | 0.62* | 8.3 | 8.3 | 8.2 |
| 0.18 | 0.31 | 7.0 | 8.3 | 8.0 |
| 0.12 | 0.21 | – | 1.4 | 3.7 |
| 0.06 | 0.10 | – | 2.3 | 1.0 |
| *glyphosate* | | – | *23.5 l/ha* | *12.4 l/ha* |
| 0.8 | – | – | 8.4 | 6.9 |
| 0.8 | AMS ** | – | 8.4 | 7.7 |
| 0.4 | – | – | 8.5 | 6.0 |
| 0.4 | AMS ** | – | 6.8 | 6.3 |
| 0.2 | – | – | 10.0 | 5.3 |
| 0.2 | AMS ** | – | 9.0 | 7.0 |

* Normally used rates for knapsack sprayer.
** AMS = 5 per cent ammonium sulphate.

TABLE 3. OIL PALM CIRCLE SPRAYING: WEED CONTROL SCORES USING GLYPHOSATE AT DIFFERENT APPLICATION RATES USING A DOUBLE-HEADED MICRON HERBI

| *Glyphosate (kg a.i./h)* | *Additive* | *Yellow outer blue inner nozzles** | | *Yellow outer yellow inner nozzles*** | |
|---|---|---|---|---|---|
| | | *38 DAT* | *104 DAT+* | *38 DAT* | *93 DAT* |
| 0.4 | – | 10 | 4.9 | 9.8 | 4.6 |
| 0.4 | 0.5% Ethokem T25 | 10 | 3.1 | – | – |
| 0.2 | – | 10 | 5.6 | 8.4 | 6.4 |
| 0.2 | 0.5% Ethokem T25 | 10 | 4.9 | 9.6 | 4.6 |
| 0.2 | 5% ammonium sulphate | – | – | 8.4 | 4.6 |

Amounts of spray/ha: *20 l/ha, **26/ha.
+DAT = days after treatment.

obtained for both machines (but with far greater productivity with a Herbi). Reducing chemical rates by one–half gave similarly acceptable results *(Figure 6)* but at rates below this, weed control was poor. Glyphosate, applied through a Herbi only as calculation showed that usage through a knapsack sprayer would be uneconomical, showed little difference between 0.8 and 0.2 kg a.i./ha. Most treatments gave good control for at least 90 days, but additives had no striking effect *(Table 2)*.

In these trials, further, recording showed that good prolonged control can be obtained with both contact and systemic herbicides where the canopy is sufficiently dense. However, at sites where light allowed thick grass develop-

*Figure 6. Rubber strips (wider than necessary) at five weeks after using gramoxone +2, 4-D amine through a Herbi at one-half normal rate. The effect continued up to at least 120 days.*

ment, contact herbicide was inferior to glyphosate, the latter also being spoiled by legume overgrowth. For most of the part, little weed control is required in mature rubber except that prior to fertiliser application, a time when there is considerable light onto the ground, so use of glyphosate is to be preferred.

*Oil palm paths*

The paths in young areas gave variable results. It was noticeable that path sections more shaded than others were still in good condition after about 120 days following glyphosate application at rates as low as 0.4 *l*/ha of Roundup. There was a slight indication that addition of 5 per cent ammonium sulphate was beneficial. Whilst good control over long periods can be expected under more closed canopies, it seems likely that it will continue to be necessary to spray more open areas more frequently than in fully mature stands until a herbicide with a longer residual effect has been identified.

*Oil palm circles*

Good results were obtained with both 0.4 and 0.2 kg a.i./ha glyphosate applied through the double–headed Herbi with both combinations of nozzles (*Table 3*). The additives used did not give any obvious increase in efficacy. Glyphosate gave a much more prolonged result than the paraquat + 2,4–D amine mixture.

*Grass control in legumes*

Whilst some conflicting results were obtained with Fusilade, at two trial sites, grass control was still at an acceptable commercial standard after almost four months since application. All grasses were controlled at both 1 and 2 *l*/ha Fusilade. In one trial, the highly translocated nature of Fusilade was particularly clear since it had obviously spread through rhizomes into unsprayed parts.

*Nursery*

Excellent results were obtained in weed control in the nursery. The good conditions for weed growth meant that the slower-acting glyphosate did not give the rapid control needed. The finer details of a nursery spray programme need to be determined but is likely to be one alternating a contact herbicide with glyphosate. Paracol at 1.3 *l*/ha gave good kill.

*Herbicide recommendations*

The suggestion made here are based on trials carried out in North Sumatra but should be applicable elsewhere. However, it is evident that a considerable amount of experimentation is still required and this could well lead to changes in recommendation as more results become available. In the interim, usage of present knowledge will still lead to very substantial economies. At the same time, it must be emphasised that the potential value of herbicides and machines cannot be fully exploited without a sound understanding of the numerous facets affecting spray application.

Based on the information available to date, recommendations are given in *Table 4* for each herbicide situation. The programme aims at the exclusion of paraquat from a spray programme and trials are in progress to substitute Paracol for a less toxic herbicide.

Obviously many estates will still have paraquat stocks and thus cannot be wasted. Provided proper precautions are taken, especially through wearing rubber boots and correct handling, there should be no danger. It is suggested that such stocks be used up only in closed canopy situations, in which they give greatest cost benefit, in sequence with glyphosate. A mixture of 160 ml Gramoxone + 80 ml 2,4–D amine per 2.5 litre bottle, sprayed using a blue nozzle, is suggested. This gives a total spray volume of 13.5 *l*/ha, of which Gramoxone is 0.9 *l* and amine 0.45 *l*

Addition of ammonium sulphate and Ethokem T25 to glyphosate solutions gave no obvious benefit in these trials. However, inclusion of ammonium sulphate at 5 per cent concentration has been recommended in *Table 4* since it is an inexpensive additive and could well be beneficial in some circumstances. Ammonium sulphate has been shown to give improved resistance of glyphosate to rainfall (Caseley, Coupland & Simmons, 1976) and may improve consistency of results where rain falls shortly after application, although this should be avoided if possible. Both Ethokem T25 and ammonium sulphate are thought to increase rates of penetration through leaf surfaces and both have allowed reductions in the amount of glyphosate used through enhanced phytotoxicity (Cherry, 1979; Miguel Fernandez & Mata Pacheco, 1978; Turner & Loader, 1980), whilst a similar effect has been reported when urea has been incorporated with dalapon in sprays (Mangoensoekarjo & Nurdin, 1978). Further experimentation is required, especially on the comparative effects of

TABLE 4. RECOMMENDED SPRAY SOLUTIONS FOR C.D.A. USING A MICRON HERBI*

| *Situation* | *Herbicide (l/ha)* | *Total volume (l/ha)* | *Nozzle colour* | *Amount of chemical per litre solution* | *Frequency* per year* |
|---|---|---|---|---|---|
| Oil palm paths – open situations. Rubber fertiliser strips – 3–4 weeks before fertiliser application. | Roundup 0.75 plus ammonium sulphate 5% | 22 | yellow | Roundup 35 ml<br>A/sulphate 50g | 3–4 |
| Edges of 'closed' oil palm and rubber fields; roadsides | Roundup 0.75 plus ammonium sulphate 5% | 22 | yellow inner<br>yellow outer | Roundup 35 ml<br>A/sulphate 50 g | 3–4 |
| Rubber paths, closed situations. Oil palm paths, closed 'dark' situations. | Roundup 0.5 | 13.5 | blue | Roundup 37 ml | 1–2 |
| Oil palm circles, closed situations. | Roundup 0.5 | 20** | blue inner<br>yellow outer | Roundup 25 ml | 1–2 |
| Oil palm circles, open situations. | Roundup 0.75 + A/sulphate 5% alternating with Paracol 1.3 | 20** | blue inner<br>yellow outer | Roundup 38 ml<br>Ammonium 50g<br>Paracol 65 ml | 2<br><br>2 |
| Oil palm and coconut nurseries | Roundup 0.75 + A/sulphate 5% alternating with Paracol 1.3 | 13.5 | blue | Roundup 56 ml<br>Ammonium 50g<br>Paracol 100 ml | 4**<br><br>4** |

* Or adaptation using a Herbi head.
** = nominal
N.B: amounts are per sprayed hectare.

additives under light and shaded conditions.

## PRODUCTIVITY

There have been numerous comparisons made of different application methods and these have shown that the technique of c.d.a. results in operating costs being reduced by over 50 per cent (Matthews, 1979). This is in keeping with the findings of this study. An indication of the savings in labour and water transport costs can be gained from practical tests on the number of times a spray container has to be refilled per sprayed hectare using a knapsack sprayer and Herbi disc:

Thus a 15 *l* knapsack sprayer fitted with a blue Polijet nozzle allows approximately 9 minutes spraytime, whereas a 2.5 *l* Herbi bottle used with a blue nozzle last approximately 28 minutes. Further improvements in work rate were obtained when the Herbi head was linked to a 15 *l* knapsack tank, as described earlier, allowing over two-and-a-half hours spray-time for each tank. Operator fatigue is reduced as there is no pumping involved and the operator simply has to walk and direct the spray head. However, in the long run fitting a 5 *l* or 10 *l* tank may prove more satisfactory for overall operation.

Some results to date on comparative productivity have been as follows:

- For selective weeding legumes for grasses, one operator with a double–headed machine could easily cover 5–10 ha/day.
- For paths or strips in rubber and oil palm, using 20 *l* of spray in a knapsack tank, work output could be increased from 0.7 km in 12.2 minutes, using a blue Polijet and a knapsack sprayer to 13.4 km in 222 minutes using a blue Herbi nozzle. Here is a clear opportunity for major labour saving. In rubber, much will depend on planting density, but coverage of 3 km of strips/hour is possible and this in Sumatra was shown to reduce costs by 60 per cent. For oil palm fields with approximately 600 m of paths the aim should be about 4.5 ha/h, allowing for non-productive (non-spraying) time.
- In mature oil palms, for which a double-headed machine is used, the aim should be that of spraying 1 ha/h for palms planted at 143 palms/ha, provided the machine has a larger spray tank fitted.
- Nursery costs can be drastically reduced. Hand weeding of the ground is the norm in North Sumatra, this being both slow and usually resulting in damage to polybags. Use of c.d.a. has resulted in a reduction from 30 mandays/ha/month to 1 manday/ha.

Cost comparisons have limited value since these will vary both between countries and between different organisations within the same country This will be particularly so with labour, and marked differences will be found between Indonesia and Malaysia since labour shortage and cost in the latter contrast sharply with the Sumatran situation.

| Sprayer | Tank capacity *l* | No. of fills/ha* |
|---|---|---|
| Knapsack | 15.0 | 13.3 |
| Knapsack | 20.0 | 10.0 |
| Herbi | 2.5 | 3.0 |
| Herbi | 15.0 | 0.47 |
| Herbi | 20.0 | 0.35 |

(*N.B: all spray amounts are litres per sprayed hectare, not per hectare of crop).

Therefore the comparison made in *Table 5* is only a rough guide and has used as its base line the cost of conventional knapsack spraying using paraquat plus 2,4–D amine as equivalent to 100 per cent. Savings through use of c.d.a. are expressed as relative percentages. These are comparative figures for a single spray round and do not reflect the value of improved standards and less frequent spraying through c.d.a. allowing the economic use of Roundup. Since the data are derived from use of a standard Micron Herbi using a 2.5 spray bottle, even greater cost differentials result when a larger spray liquid tank has been filled, with less time lost through bottle filling and changing.

## DISCUSSION

The older concept of spraying to run-off to achieve proper dosage or coverage is clearly an unnecessary waste of spray. Use of c.d.a. for herbicide usage will allow both proven and new herbicides to be used much more effectively and economically than high volume application. The c.d.a. technique is not new but has not been widely used in the oil palm and rubber industries. However, the writers forecast that c.d.a. will become a widely–used practice in plantations, with associated considerable economies. In addition to direct savings, c.d.a. will assist in maximising the benefits of fertiliser application and

TABLE 5. COMPARISON OF STRIP SPRAYING IN MATURE RUBBER USING STANDARD KNAPSACK AND MICRON HERBI EQUIPMENT

| Equipment | *Chemical (kg a.i./ha)* *Paraquat* | *2,4–D amine* | *Cost (%)* *Chemical* | *Water* | *Labour* | *Changes in cost (%)** |
|---|---|---|---|---|---|---|
| knapsack | 0.16 | 0.2 | 100 | 100 | 100 | |
| Herbi | 0.16 | 0.2 | 100 | 10 | 20 | – 26 |
| Herbi | 0.08 | 0.1 | 50 | 10 | 20 | – 60 |
| | | *glyphosate* | | | | |
| knapsack | | 0.27 | 308 | 100 | 100 | +242 |
| Herbi | | 0.10 | 123 | 10 | 20 | – 10 |
| Herbi | | 0.06 | 68 | 10 | 20 | – 47 |

* Costs were based on 1982 prices in North Sumatra. For further details see text.

improving soils generally but especially through increasing soil organic content.

In this consideration of weed control, we have not overlooked other recent developments in spray equipment for c.d.a. One of the most widely publicised has been the use of electrostatics to break up the spray liquid into charged droplets which are then attracted to the oppositely charged target surface (Coffee, 1979). This equipment seems to be still some way from commercial availability for herbicide usage and has a disadvantage at present over the spinning disc technique in that it lacks much flexibility through requiring specific oil–based formulations. Very low volume (VLV) nozzles for use on knapsack sprayers require vital pressure control and constant height to give required results. There thus remains the important factor of operator fatigue, and droplet production is not as efficient as that obtained by rotary atomisation, as well as volume per sprayed unit being greater. The Micron Herbi used is already widely used in tropical agriculture and is readily available. Therefore, even if later developments bring further improvements, immediate use of the Micron Herbi, or developments from it, would significantly reduce herbicide usage costs.

Herbicides with different modes of action may behave differently when applied at high and low volumes. Contact herbicides, *e.g.* paraquat, may perform more consistently at high volumes whereas translocated herbicides as glyphosate are more effective at low volumes, allowing reductions in the recommended rates of application (Caseley *et al.*, 1976; Turner & Loader, 1978). In the Sumatran trials, equivalent results were obtained with paraquat at both high and low volumes. Very low rates of glyphosate were effective when applied at low volumes with the Herbi but it is unlikely that these rates will give similar control at high volumes, although no comparison was made.

There were some observations from the trials which would generally affect c.d.a. operations wherever this method is used. These included:

- Weather: The only poor result with glyphosate was in a trial where heavy rain fell about two hours after application. Organisation must be such that most spraying is carried out during periods of the year which are usually drier, and enough flexibility inbuilt in maintenance programmes to avoid spraying when rainfall seems likely within six hours of spraying. This can be done, especially with the flexibility provided by smaller and more efficient groups using c.d.a. techniques. It is better to have spray operators doing something else, or even nothing, than to spray under unsuitable conditions leading to virtually total waste.

- Contact herbicides: The use of contact herbicides, particularly paraquat, in open situations looks spectacular quickly. However in the absence of repeated applications, their long-term effect is far less than that of glyphosate.

- Light penetration: Effects of herbicides were considerably influenced by canopy density and its effects on ground flora composition. Thus contact herbicides have long–lasting effects under darker conditions but their effect is comparatively short–lived in open situations in the absence of repeated spraying. Glyphosate activity is also affected by light intensity (Moosavi Nia & Dore, 1979; Wong, 1981) and in high light situations inclusion of spray additives (*e.g.* ammonium sulphate) may prove important.

- Changes in weed flora have been pronounced. Glyphosate spraying has been followed by prolific growths of soft weeds which have presumably been suppressed by grasses which dominated the flora when contact herbicides were used. It is therefore likely that alternating rounds of sprays of systemic and contact herbicides will need to be made, with the correct pattern only emerging after two to three years' use and observation. Incorporation of a residual herbicide is likely to be valuable.

There is, therefore, a strong necessity for management to take all local conditions into account when deciding on a spray programme. Particular attention will need to be paid to rainfall, amount and type of vegetation, subsequent weed regeneration, and the type of herbicide which will give greatest long–lasting effect. Flexibility in decision making is essential.

One side effect observed which could be very beneficial in oil palm plantings was the profuse development of soft weeds other than grasses which followed glyphosate sprays. These weeds are likely to be of considerable benefit in integrated pest management, particularly through maintaining biological control of leaf-eating pests. Roadside and field edge vegetation maintenance in oil palm estates should be by glyphosate to exploit this potential advantage.

For grass removal in legumes, a major requirement when manual labour is used is to eliminate the inefficiency which accompanies hand weeding. Most grasses are only broken off or incompletely pulled, so that regeneration automatically leads to a need for further futile hand-weeding. Successful use of a translocated herbicide would mean far fewer rounds of grass removal, as well as being able to extend economically the period of grass–free cover maintenance right through to maturity in most instances. The initial impression gained was that a second application of Fusilade after four to five months would virtually eliminate grasses for all practical (commercial) purposes. Unfortunately, price of Fusilade may restrict its usage in situations of low labour cost and if used at the recommended rate of two to four *l*/ha, although trials showed that successful control could be obtained at half of the rates recommended. At the same time, a re–examination is required into the use of Roundup as a selective herbicide in grasses. This function has long been proposed by the manufacturers (Hussein & Wong, 1978), and this aspect of Roundup usage by c.d.a. could easily be tested. Great reduction in grass removal expenditure is a major requirement in minimising costs during the immature phase and there is now considerable evidence that this can be easily achieved.

Mikania control is one of the remaining problems. Use of the rope wick technique has not proved successful so far. There is also the problem of weeded circles becoming rapidly invaded by legumes, requiring hand pulling at intervals of about four weeks, but it should be possible to replace this by herbicide treatment. One drawback of the Herbi is that it is unsuitable for spot–spraying other than large infested areas. Work is continuing.

Whilst this paper has concentrated on c.d.a. usage in oil palm and rubber, use of this approach in other plantation tree crops would obviously be worthwhile. Early indications are that Micron Herbi usage is already giving great economies in weed control in cocoa in Papua New Guinea, and preliminary trials there have also shown it to be ideal for use in coffee. Similar good results would be expected in coconut. Nor is the value of c.d.a. restricted to herbicide usage. Treatment of diseases and pests, particularly in nurseries, is just one example of possible use.

An outcome of this initial examination of c.d.a. usage has been that the trials provided a clear demonstration of the need for further experimentation to minimise chemical costs and to test additional herbicides. Organisational details have also to be worked out. Some trials will be long term since there are associated floristic changes. Therefore, wherever c.d.a. is being introduced the results must be looked at with the possibility of flexibility always in the background, *e.g.* the necessity for alternating sprays for a particular flora. Thought and common-sense are important ingredients of c.d.a. usage, as well as great attention to detail. It should be apparent that introduction of a weed control technique which is both almost untried in most tropical plantation crops and differs considerably from that which has been used for many years, can only be achieved over a long period. Nevertheless, early results have been so convincing that large areas have already been changed to the new system, with very satisfactory results.


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