Research Summary

A NON-TILLAGE METHOD FOR SEEDING PERENNIAL GRASSES USING PARAQUAT ON DOWNY BROME-INFESTED RANGELANDS

Raymond A. Evans, Richard E. Eckert, Jr. and Burgess L. Kay
Crops Research Division, Agricultural Research Service, USDA, University of Nevada, Reno, Nevada and University of California, Davis, California

Summary A non-tillage method of seeding perennial grasses using paraquat shows promise on some areas of downy brome-infested rangelands. Paraquat at rates as low as 0.5 lb/ac has given adequate and consistent weed control for good seedling growth of perennial grasses. Early application dates show most promise for seedling establishment. Limits for success of this method both geographically and from year to year have not yet been well defined.

INTRODUCTION

Control of downy brome (*Bromus tectorum* L.) and other herbaceous weeds at time of seeding of perennial grasses is critically important as an aid for seedling establishment in a non-tillage operation, in rangeland formerly occupied by big sagebrush (*Artemisia tridentata* Nutt.) in Nevada and northeastern California.

The big sagebrush community occurs widely in the western states and in Nevada and northeastern California at elevations of 4,000 to 8,000 ft. Precipitation is relatively light, ranging from 8 in. at the lower elevations to 20 in. in the higher mountains. Precipitation principally comes as snow in the winter and rain in the spring. Commonly the summer and fall are dry or with little precipitation. Summers are warm with extremes above 100 F and winters are cold with extremes of -10 to -30 F often occurring. Soils are quite variable but can be generally characterized as browns and chestnuts varying in depth from about 1 to 4 ft.

Large areas of the big sagebrush community are in depleted condition with almost pure stands of big sagebrush having little or no perennial grass understory. Heavy grazing coupled with big sagebrush characteristics of aggressiveness, low palatability, and high drought resistance have brought on this condition.

Downy brome grass alone, or more often, in association with other annual weeds has invaded these depleted stands and formed a sparse to heavy understory.

The big sagebrush-downy brome ranges in good forage years such as 1964 are serious range-fire hazards because of the build up of dry grass beneath the brush plants. Fires kill most of the sagebrush and leave solid stands of downy brome and other annual weeds.

The sagebrush defoliating insect (*Aroga websteri* Clark), has killed large areas of sagebrush in recent years, especially in 1962 and 1963. In addition, intentional sagebrush clearing either by chemical or mechanical means for seeding has been carried out on a large scale. In some of these areas seedings have failed leaving them open for invasion by downy brome.

Pure stands of downy brome produce more forage for livestock than does depleted sagebrush range. However, downy brome is less desirable than perennial grasses such as crested (Agropyron desertorum (Fisch.) Schult.), pubescent (A. trichophorum (Link) Richt.) or intermediate wheatgrass (A. intermedium (Host) Beauv.).

Compared to seeded perennial grasses, downy brome has a short, green-feed period, slow growth in the spring, great variability in yield from year to year and creates a high fire hazard.

Because of its being an annual, downy brome's year to year variability alone creates a questionable base for a livestock operation.

To seed perennial grasses successfully into downy brome-infested areas, adequate weed control must be accomplished in seed-bed preparation.

Conventional methods of disking and seeding with a grain drill in the spring, or late fall in years when downy brome emerges before winter, offer adequate seed-bed preparation but often provide poor control of downy brome. Also, these methods are not suitable for rough terrain or rocky soils. Therefore, more efficient and usable methods are needed to convert areas infested with downy brome into perennial grasslands.

METHOD AND MATERIALS

A study was begun in 1962 to evaluate non-tillage methods using paraquat for control of downy brome and other annual weeds with simultaneous seeding of perennial grasses.

The first trial compared paraquat and cultivation for downy brome control and subsequent seeding of perennial grasses. The area of the trial was in northeastern California in the big sagebrush type. This area had burned about 20 years previously and at the time of study was infested with downy brome and tansy mustard (Descuraina pinnata (Walt.) Britton).

Paraquat was sprayed at logarithmic rates from 2.0 to 0.04 lb/ac (cation) with X-77 (a blended surfactant containing alkylarylpolyoxyethylene glycol, free fatty acids and isoproponal) at 0.1% vol./vol.

Morning and afternoon applications of paraquat were compared in this study. Topar pubescent wheatgrass was drilled in the paraquat, cultivated and undisturbed check strips after spraying.

Paraquat to about 0.5 lb/ac gave excellent control of downy brome and tansy mustard. Some control was seen down to very low rates (0.09 - 0.18 lb/ac). Late afternoon application of paraquat gave better weed control than morning application, especially at rates lower than 0.5 lb/ac.

Six to 7 vigorous seedlings per ft of row of pubescent wheatgrass were established in the paraquat strips at rates of about 0.5 to 3.0 lb/ac. No injurious effects to the grass seedlings were noted at even the highest rate of paraquat. Comparable stands were established in cultivated strips while in the undisturbed downy brome less than 1 weak, spindly seedling was counted per ft of row.

At rates below 0.5 lb/ac more seedlings were found in the afternoon-applied paraquat than in the morning applied.

Second-year yields of wheatgrass reflected the effects of weed control in the seeding year. Pubescent wheatgrass, established with the aid of paraquat applied in the afternoon at rates of 0.5 lb/ac and higher, yielded over 1,000 lb/ac oven-dry forage.

Yields of wheatgrass established by means of cultivation were no different from those of the afternoon-applied paraquat. Wheatgrass established with morning-applied paraquat yielded less. Yield of plants seeded without weed control was about 30 lb/ac.

The following year a series of trials in Nevada and northeastern California was established to confirm first-year results and to determine the general feasibility of the method.

Trials were established on 5 locations, 4 of which were areas of previous fires, and the fifth an area of a seeding failure. All were infested with downy brome and broadleaf weeds. Notable among the broadleaf weeds were tumbling mustard (*Sisymbrium altissimum* L.) and Russian thistle (*Salsola Kali* L. var. *tenuifolia* tausch.)

Paraquat with X-77 at 0.1% vol./vol/ was applied logarithmically at rates from 2.0 to .06 lb/ac. Unsprayed strips were also included in the experimental designs. Crested and intermediate wheatgrasses were drilled in sprayed and unsprayed strips. Seeding was done either immediately before or after spraying.

Dates of paraquat application and seeding ranged from February 25 to May 1 in these trials.

Downy brome plants were scorched and some measure of control was seen from paraquat as low as .06 lb/ac. However, clean initial control and fair to excellent end-of-season control were achieved by paraquat at about 0.5 lb/ac. Despite regrowth after spraying, average yield reductions of downy brome were 80 to 90% with paraquat at 0.5 to 2.0 lb/ac.

Spraying before seeding gave better weed control than spraying after because downy brome plants, or at least part of the plants, were covered by soil from the drilling and escaped the spray. Consequently, weed-infested drill rows resulted even at high rates of paraquat.

Average seedling number of intermediate wheatgrass the first year was 6 per foot of row with rates of paraquat from 0.5 to 2.0 lb/ac compared with about 1 on unsprayed plots. Crested wheatgrass seedlings were 0.2 per foot of row on unsprayed plots compared to about 2.5 with paraquat at 0.5 lb/ac or more.

Paraquat was not effective in controlling tumbling mustard though it had been with tansy mustard the previous year. At the 2 lb/ac rate, yield of mustard was usually numerically greater than at lower rates because of reduced downy brome competition. In later studies, 0.5 lb/ac of 2,4-D low volatile ester mixed with paraquat provided good control of tumbling mustard and Russian thistle without injuring perennial grass seedlings.

Date of seeding was an important factor in establishment of seedlings. The earlier the seed was drilled into the ground the better chance for success.

Date of spraying was not as important as that of seeding. However, amount of season-long weed control did vary from spraying at different dates. At one location the earliest spray date (February 25) gave poorest season-long weed control because of later germination and regrowth of downy brome plants not completely killed. The latest date (April 24) at this location gave best season-long control. However, number, size, and vigor of perennial grass seedlings were much greater at the end of the growing season from the earliest spraying and seeding.

Larger, more vigorous seedlings from earlier plantings probably resulted from more time during the spring to grow under favorable conditions and deeper root penetration that may have aided in survival near the end of the season when conditions were very dry.

Weed control was quite consistent among locations with one exception. Here regrowth of downy brome resulted in poor control 6 weeks after spraying.

Seedling growth of seeded grasses was more dependent upon site than was weed control by paraquat. In 1963, final counts of seedlings did not differ much from one area to another; but seedling size and vigor did vary markedly in respect to location. Preliminary results from later studies indicate that site difference in the big sagebrush community is an important factor in seedling establishment using this technique.

Although severe infestations of grasshoppers in most plots ate seedlings to the ground level during the summer, perennial grasses became established to some extent where high rates of paraquat had been applied and where almost perfect weed control had enhanced first-year growth. Second-year yields were not taken in these instances.

At the northeastern California site, where grasshoppers had been no problem, second-year yield of intermediate wheatgrass was increased from nothing on unsprayed plots to about 300 lb/ac where paraquat at 0.5 to 2.0 lb/ac was applied the seeding year.

On some sites, promising results have been obtained thus far in non-tillage seeding of perennial grasses with the use of paraquat for weed control in downy brome-infested areas of the big sagebrush community. The fast contact action and rapid deactivation in soil of paraquat permit drilling of grass seeds immediately after spraying which facilitates a one-step operation.

Success of this technique, like any other method of spring seeding in the big sagebrush community, is limited to years of adequate spring rainfall and is a better risk on some sites than others.

Studies are still under way to define, more precisely, the conditions of site and of year where paraquat spraying and spring seeding can successfully be employed.

Research Summary

PARAQUAT - AN AID TO THE SEEDING AND MANAGEMENT OF RANGELANDS IN THE MEDITERRANEAN CLIMATE OF CALIFORNIA

Burgess L. Kay
University of California, Department of Agronomy, Davis

Summary Paraquat sprayed at 0.5 lb/ac at the time of seeding hardinggrass (*Phalaris tuberosa* L. var. *stenoptera* (Hack.)Hitch.) and subterranean clover (*Trifolium subterraneum* L.) effectively controlled annual weeds, mostly medusahead (*Taeniatherum asperum* (Simk.) Nevski), and resulted in establishment of the seeded species.

Paraquat was also shown to remove both annual grasses and broadleaves from established stands of rose clover (*T. hirtum* All.), subterranean clover, and hardinggrass without permanent damage to these species. If applied early in the growing season yields were not reduced. Protein content of the remaining forages was increased following spraying or clipping. Repeated clipping had similar effects on weed control and forage quality as spraying with paraquat.

INTRODUCTION

Paraquat has shown great promise for weed control during seeding in the downy brome (*Bromus tectorum* L.) ranges of northeastern California as reported by Evans et al. earlier in this conference. With this success it seemed desirable to try a similar technique in the not-so-similar mediterranean type climate which most of California enjoys.

The resident vegetation is mostly annual grasses and forbs which germinate in October or November and mature and dry in May (about an eight-month growing season). Winter temperatures are mild enough to permit a minimum amount of plant growth, with the major portion of growth occurring in the spring. Annual grasses, such as medusahead (*Taeniatherum asperum* (Simk.) Nevski), foxtail fescue (*Festuca megalura* Nutt.), and wild barleys (*Hordeum* spp.), dominate the herbaceous weed problems in much of California.

A common approach to improving these ranges is the planting of good forage species such as rose clover (*Trifolium hirtum* All.), subclover (*T. subterraneum* L.), and hardinggrass (*Phalaris tuberosa* L. var. *stenoptera* (Hack.) Hitch.). The greatest problem in the establishment of these species is the severe competition from the resident annual grasses and forbs. Heady (1956) found the number of resident plants early in the growing season to vary from 20 to nearly 100 per square inch. These annuals are not only a deterrent to the establishment of seeded forage plants, but may persist in abundance in established stands of the seeded species and reduce the quantity and quality of forage. Thus, we need a contact herbicide for use during seeding and also a selective herbicide to remove the weedy annuals from the established seedings. Paraquat shows promise for satisfying both of these needs.

Weed control during seeding

METHODS AND MATERIALS

Seeding and spraying were done on November 2, 1962, about two weeks after the first fall rain. The newly germinated crop of medusahead was 1-2 inches high and covered with a heavy accumulation of medusahead litter. (Approximately 4,000 lb/ac.) Paraquat was sprayed in eight-inch bands at 0.5 lb/ac cation per sprayed acre immediately ahead of the drill openers (22-inch spacing) during the seeding operation. A mix of equal parts hardinggrass and subterranean clover was planted at 8 lb/ac, and single superphosphate banded beneath the seed at 200 lb/ac. Unsprayed plots were planted as checks.

Similar trials were conducted in seven locations the following fall (1963) with modifications. Various band widths were tested - narrow (5-8 in.), wide (9-12 in.), full spray coverage, and unsprayed checks. Also included as the main plot of the split plot design were two fertilizer banding treatments, 16-20-0 at 100 lb/ac and single superphosphate at 100 lb/ac. Four replications were fenced and four left open to grazing at each location.

RESULTS AND DISCUSSION

Hardinggrass seedlings were mere threads of 2-3 leaves and 2-7 in. high in the unsprayed rows at the end of the first growing season as compared to robust plants about 12 in. high and 1-6 leafy tillers in the 8-in. weed-free band where paraquat was sprayed. As could be predicted, the plants in the sprayed strips lived through the dry summer, while most of those in the unsprayed checks died. Samples the following winter showed the checks to be 3% stocked with hardinggrass (12-in. square quadrats) and the band sprayed area 76% stocked. Clover established well even in the checks, although the second year after seeding the clover stand was considerably better in the bands sprayed with paraquat.

Final measurements of hardinggrass established in the second trial have not been completed. However, preliminary observations indicate hardinggrass establishment will be similar to the first year's experiment on at least some of these sites. Clover establishment was significantly increased by paraquat treatments in all seven locations when fenced, and five of the seven when left open to grazing (grazing usually gives adequate weed control for clover establishment and is the recommended practice). There were no differences between widths of bands sprayed - the narrow band was as effective as full spray coverage. There was also no difference between fertilizers in the grazed trials, but the 16-20-0 did reduce the stand on two of the fenced trials due to the increased competition resulting from nitrogen fertilization.

Among the most important points learned is that a heavy litter residue (always present with medusahead because of its unpalatable nature) is desirable. Heavy litter accumulations promoted complete germination of the weeds following the first rains, while in areas of light litter only part of the weeds germinated. Weed control in minimum litter accumulation was only temporary, as more weeds germinated after subsequent rains.

The technique of spraying paraquat during the seeding operation has a great potential if succeeding trials continue to be this successful. The areas involved lie between the lands which can be safely cultivated and range lands which are too steep or rocky to traverse with a crawler tractor. Between these two extremes are many thousands of acres which could be drilled using the rangeland drill developed by the U. S. Forest Service. The herbicide could be applied either by aircraft as a separate operation or during the seeding by a sprayer mounted on the drill or tractor.

Selective weed control in established range seedings

Recent studies by the author have investigated the most promising selective herbicides for use in range seedings. 4-(2,4-DB) was shown to selectively remove annual broadleaves from clover seedings, while dalapon was demonstrated to have limited possibilities for removing annual grasses without damage to clover (Kay, 1963).

Paraquat applied under weed-free (cultivated) conditions affected neither herbage nor seed yield of rose or subclover (Kay, 1964). The addition of a surfactant (X-77 @ 0.05% vol./vol.) caused a reduction in yield of rose clover, but not of subclover. Varying the concentration of the surfactant had no significant effect.

In a companion study paraquat sprayed at 0.5 lb/ac removed weedy annual grasses such as medusahead, foxtail fescue (*Festuca megalura* Nutt.), and wild barleys from range seedings of rose clover and subclover with only temporary damage to the clovers. Applications were made during the period of slow growth in the winter.

The study reported below investigated the effects of paraquat and clipping not only on composition, but also quality and yield of an established hardinggrass-subclover pasture.

METHODS AND MATERIALS

Paraquat was applied at 0.5 lb/ac with and without a surfactant (X-77 @ 0.05% vol./vol.) on two dates, November 11, 1963 and February 19, 1964. These dates represent early and late in the cold winter period of minimum growth. The subclover was 3 trifoliate leaves at the first spray date and a vegetative rosette of many leaves on the second date. One-half of each plot, including the unsprayed check, was clipped at 2 in. periodically during the growing season (a total of 5 clippings). Clipping was to simulate the recommended management practice of grazing to prevent the pasture from becoming grass dominant. The experiment was a split plot design with 5 replications.

RESULTS AND DISCUSSION

All spraying, clipping, or combinations of spraying and clipping reduced the annual grass (from 66% annual grass on checks to an average of 2.3% on the treated areas). There was no difference between clipping alone or between dates of spraying. Seeded species, including hardinggrass, were increased by all treatments (33% on the check compared to an average of 96.8% on treated areas).

Forage quality was generally increased by all treatments. Protein was 10.7%, 16.0%, 15.5%, and 17.7% for the check, clipping, early spray and late spray, respectively.

Spraying at the early date delayed forage production until March, but subsequent growth equalled total seasonal production on the check. Plots sprayed at the late date yielded significantly less than the check, apparently because the remaining growing season was too short for maximum production. There was no significant difference in yield between dates of spraying or the use of a surfactant. Also, clipping had no effect on total yield, a single clip yielded the same as the sum of 5 clippings.

References

HEADY, HAROLD F. (1956) Evaluation and measurement of the annual type. J. Range Mgmt. 9, 25-27.

KAY, BURGESS L. (1963) Effect of 4-(2,4-DB) and dalapon on three annual trifoliums. Weeds 11, 195-198.

KAY, BURGESS L. (1964) Paraquat for selective control of range weeds. Weeds 12, 192-194.

RENOVATION OF PERMANENT PASTURES WITH HERBICIDES

Elroy J. Peters
Agricultural Research Service, U. S. Department of Agriculture and Missouri Agricultural Experiment Station, Columbia, Missouri

Summary Paraquat and dalapon were found more effective than cacodylic acid for killing turf in the Southern Corn Belt of the United States. Fall or spring applications were more effective than summer applications for killing turf. Paraquat is highly promising for pasture renovation because it disappears rapidly and is effective at low dosages; however, it is erratic, perhaps due to seasonal variation in the physiology of turf.

INTRODUCTION

Work with herbicides for pasture renovation in the United States has been meager compared with the extensive studies reported by British weed scientists.

Experiments reported here were on sites somewhat representative of more than 4 million acres classified as bluegrass pasture in Missouri, Southern Illinois, Southern Indiana and part of Kentucky. The botanical components of the more productive of these pastures consist of *Poa pratensis* L., with legumes such as annual lespedezas (*Lespedeza striata* (Thunb.) Hook. & Arn. and *L. stipulacea* Maxim.), white clover (*Trifolium repens* L.), and hop clovers (*Trifolium agrarium* L. and *T. procumbens* L.). In addition to these species, grasses such as *Poa annua* L., *P. compressa* L., *Aristida oligantha* Michx. and *Agrostis alba* L. are often present in poorer pastures.

The botanical composition of the pastures fluctuate from year to year, depending upon precipitation. Short periods of drought occur nearly every year and may sometimes last 3 or 4 years. During these drought years, lespedeza decreases; white clover and hop clovers disappear; and the vigor and quantity of bluegrass is reduced. Drought combined with a decline in fertility and generally poor grazing management, leaves the sod open to invasion by weeds.

Broadleaved weed species often present are Vernonia baldwinii Torr. and V. altissima Nutt., Solanum carolinense L., Eupatorium serotinum Michx., Ambrosia artemisiifolia L., Ambrosia bidentata Michx., Achillea millefolium L., Erigeron canadensis L., and E. annuus (L.) Pers. Winter annual grass species such as Bromus tectorum L., Bromus secalinus L., Bromus japonicus Thumb. and Hordeum jubatum L. are often present. These annual weed grasses, when immature, are readily eaten by animals, but they mature rapidly and become unpalatable. They are also unreliable as a forage source because the fluctuation in rainfall affects production.

The objective of the work at Missouri has been to explore the possibilities of killing the existing turf and replacing it with more productive and drought-tolerant species such as Bromus inermis Leyes, Dactylis glomerata L., Festuca arundinacea Schreb., and Lotus corniculatus L.

The utility of dalapon for pasture renewal is well-known to British workers (1,2,4,5). Information in the United States shows that dalapon (2,2-dichloropropionic acid) is superior to TCA (trichloracetic acid) for killing grass (4,7,8). The 8 lb/ac rate needed in Missouri is expensive; and the additional weed control required after sowing forage species adds to the cost. Futhermore, dalapon is somewhat slow in killing grasses and residues that remain after spraying delay seeding of grasses. These problems make the use of dalapon questionable under Missouri conditions. Turf-kill by means of dalapon is excellent; and 8 lb/ac is used as a standard in our experiments. Paraquat (1,1-dimethyl-4,4-bipyridinium salt) and cacodylic acid (dimethylarsenic acid) are of more current interest because they leave little residue after spraying, and, in the case of paraquat, the dosage rate is low.

METHODS AND MATERIALS

All experiments were randomized complete block designs with 3 or 4 replications. Herbicides were applied in 40 gal/ac of water at 40 psi. Plots were 7 ft by 20 ft in size. Tillage was not used in conjunction with herbicides because the main objective was to accomplish renovation without tillage.

Experiment 1

Preliminary work with up to 15 lb/ac of cacodylic acid indicated that its performance is erratic and not as effective as 8 lb/ac of dalapon. Experiment 1 was initiated to evaluate combinations of dalapon and cacodylic acid, and to determine whether time of application influences kill. On September 27, 1961, 8 lb/ac of dalapon, 15 lb/ac of cacodylic acid, and a mixture of 4 lb/ac of dalapon and 10 lb/ac of cacodylic acid were applied. Split applications were accomplished by applying 4 lb/ac of dalapon to 4 plots per replication, and by applying 5 and 10 lb/ac of cacodylic acid to 2 of the dalapon plots on October 21, 1961. The same rates of cacodylic acid were applied to remaining dalapon plots on March 31, 1962.

Rows of Dactylis glomerata L., Festuca arundinacea Schreb, Medicago sativa L., Lotus corniculatus L. and Phleum pratense L. were drilled across the plots with a grain drill on April 17, 1962. The kill of turf was estimated visually on April 18, 1962.

Experiment 2

Plots were sprayed on August 13, 1963 with 1/2, 1, and 2 lb/ac of paraquat, 8 lb/ac of dalapon, 15 lb/ac of cacodylic acid and a mixture of 4 lb/ac of dalapon and 5 lb/ac of cacodylic acid. The herbicides were applied to a thin bluegrass sod that was actively growing after heavy rainfall following a drought. Grasses and legumes were drilled into the area with a grain drill in early September. X-77 (alkylarylpolyoxethylene glycols) at .1% v/v was used as a surfactant with paraquat. Visual estimates of the percent kill of turf were made.

Experiment 3

A thin bluegrass sod containing annual Bromus spp. was sprayed on May 1, 1964, when moisture was favorable and grasses were growing vigorously. Paraquat at 1/2, 1 and 2 lb/ac and dalapon at 8 lb/ac were used. One tenth percent X-77 on a v/v basis was used as a wetting agent with paraquat. Turf and weed kill were estimated visually on June 16, 1964.

RESULTS

In the first experiment we reasoned that 4 lb/ac of dalapon would partially kill and weaken turf, so that 5 or 10 lb/ac of cacodylic acid applied at a later date would eliminate the remaining grasses (Table 1). When the plots were observed on October 26, 1961, only the fall applications of herbicides had been applied to plots that were to receive a fall and spring treatment. The kill with dalapon on these plots was somewhat less than where the combinations had already been applied. The addition of cacodylic acid to these plots in the spring increased the kill to nearly 100 percent.

Kill of turf increased slightly during the winter on some plots that had been treated in the fall, but the turf treated with 15 lb/ac of cacodylic acid recovered considerably, while that treated with 8 lb/ac of dalapon was nearly eliminated.

The grasses and legumes drilled into the plots germinated and grew normally for several weeks and then died due to an unusually droughty spring. Because annual weed grasses such as Setaria and Digitaria came in during the summer, control of these grasses would have been necessary if the forage seedlings had survived.

Table 1

Estimated Kill of Turf on April 18, 1962

Treatments		10/26/61	4/18/62
Fall Application (9/27/61)			
8 lb/ac dalapon		91	99
15 lb/ac cacodylic acid		94	32
4 lb/ac dalapon + 10 lb/ac cacodylic acid		97	96
Split Application-Fall (9/27/61 and 10/21/61)			
4 lb/ac dalapon + 5 lb/ac cacodylic acid		97	98
4 lb/ac dalapon + 10 lb/ac cacodylic acid		87	99
Split Application			
Fall (9/27/61)	Spring (3/31/62)		
4 lb/ac dalapon	5 lb/ac cacodylic acid	85	95
4 lb/ac dalapon	10 lb/ac cacodylic acid	77	99

Visual estimates of the amount of bluegrass turf remaining in experiment 2 on September 8, 1963 (Table 2) showed that paraquat at 1 and 2 lb/ac, dalapon at 8 lb/ac and cacodylic acid at 15 lb/ac killed bluegrass sod about equally. One-half lb of paraquat and the mixture of cacodylic acid and dalapon were inferior to other treatments. The kills observed in September, however, were apparently only top-kill in most cases, because observations in the spring of 1964 showed that all plots except those treated with 8 lb/ac of dalapon had recovered.

Table 2

Estimated Kill of Turf on September 8

After Treatment on August 13, 1963

Treatment	% Kill
1/2 lb/ac paraquat	76
1 lb/ac paraquat	82
2 lb/ac paraquat	85
8 lb/ac dalapon	86
4 lb/ac dalapon + 5 lb/ac cacodylic acid	78
15 lb/ac cacodylic acid	84
Check	38

Kill of grasses was complete, or almost complete, with spring applications of 1 and 2 lb of paraquat and 8 lb of dalapon (Table 3). Close observation later in the summer showed that the bluegrass failed to recover. Weed grasses that germinated after herbicide treatments became numerous in the plots, indicating that additional weed control measures would be needed to assure a stand of forage species.

Table 3

Percent Turf and Weeds Present on June 16

After Treatment on May 1, 1964

	Percent		
Treatment	Bluegrass	Weed Brome	Weed Grass
1/2 lb/ac paraquat	20	3	48
1 lb/ac paraquat	2	1	55
2 lb/ac paraquat	0	0	36
8 lb/ac dalapon	4	0	21
Check	53	16	19

DISCUSSION

Results indicate that in the Southern Corn Belt of the United States, cacodylic acid is much inferior to dalapon. These results contrast with those reported by Sprague et al. in New Jersey (8) where excellent kill of bluegrass sod was obtained with cacodylic acid. In Missouri the top growth was severely browned from the contact effects of cacodylic acid; however, the herbicide apparently was not carried to the underground portions of the plant or at least not in quantities adequate to kill the plants.

The experiments presented herein indicate that the success of renovation depends on weather conditions at the time of treatment and at the time of seeding. For the Southern Corn Belt we recommend that pasture renovations begin with mechanical destruction of the turf in July or August after proper fertilization. Turf dies easily during hot dry summer weather. Sowing is then done in early September. Results to date, in Missouri and elsewhere, indicate that the substitution of herbicides for tillage may not be practical during July and August when poor kill of turf is generally obtained with herbicides (4,6). The application of paraquat in late summer was not directly compared with spring applications in the same experiment; but a late summer (Table 2) and a spring experiment (Table 3) were put out in the same pasture. Spring applications of herbicide killed the turf more readily than did summer applications. The late summer experiment was treated on August 14 when bluegrass was green and evidently recovering from summer dormancy after 3 in of rain had fallen between July 27 and August 12. Temperature ranged from 60 to 85°F. Apparently the physiological condition of the grass in the summer prevented the paraquat from killing the underground plant parts. Paraquat did not kill the top growth of grass as rapidly in late summer as it did in spring. Photo inactivation of paraquat may be greater in summer than in spring, but this is probably not responsible for the difference in activity because other herbicides also fall short in the summer (4,6).

Because in Missouri the kill of turf is more dependable from fall or spring applications, seedings will have to be done in spring. The main objection to spring seeding is that abundant weed seeds in the old turf cause severe weed infestations in the spring. Methods of controlling weeds, especially weed grasses, need to be developed in spring seedings. If weeds can be controlled, early spring seedings will generally prove more satisfactory because moisture is usually abundant and insect pests are at a minimum. We recommend seedings in late March or early April, so that seedlings will be established before dry weather occurs in June and July. To accomplish early spring seedings herbicides may have to be applied in the fall. If the grass has to be actively growing before the herbicide is effective, spring applications may cause some delay in seeding.

Seeding into dead turf with a grain drill has generally been more successful than has been shown in the experiments discussed here. Sometimes, however, the drill disks fail to cut into the turf sufficiently to make a slit for the seed to contact soil. More work should be done to develop tools that will place forage seeds so that they make good contact with the soil.

Our work indicates that paraquat is erratic but proper timing of applications make it effective. It is inactivated rapidly and the dosage is low so that it has considerable promise as a renovatio herbicide.

REFERENCES

1. DAVIES, C. E. et al. (1960) Hill Pasture Improvement with Dalapon. Proc 5th Brit Weed Control Conf.

2. ELLIOT, J. G. (1960) The Evaluation of Herbicidal Activity on a Mixed Sward. Proc 8th International Grassland Congress, 267-271.

3. GARDNER, A. L. (1959) Dalapon to Help Oversowing. Agr 66, 118-122.

4. HARRINGTON, J. D., J. B. WASHKO (1962) Sod Subjugation with Herbicides for Pasture Renovation. Penn State Exp Sta Bull 694.

5. JONES J., (1962) Dalapon as an Aid to Sward Renovation. Proc 6th Brit Weed Control Conf. 65-74.

6. PETERS, R. A. (1960) Observations on the Use of Herbicides for Renovation of Non-tillable Pastures. Proc NEWCC 14, 314-319.

7. SPRAGUE, M. A. (1952) The Substitution of Chemicals for Tillage in Pasture Renovation. Agron J 44 405-409.

8. SPRAGUE, M. A. et al. (1963) Pasture Improvement and Seed-bed Preparation with Herbicides. New Jersey Agr Exp Sta Bull 803.

THE USE OF HERBICIDES FOR RENOVATION AND IMPROVEMENT OF GRASSLANDS

W. R. Furtick
Oregon State University; Corvallis, Oregon; U.S.A.

Summary Work in the United States of America dealing with the use of herbicides for grass control in renovating herbage croplands is reviewed. Extensive work in the eastern U.S.A. on predominately bluegrass *Poa pratensis* sods indicate dalapon or dalapon-amitrole or dalapon-cacodylic acid mixtures are effective in sod killing prior to reseeding. Work in the western U.S.A. with a wider variety of annual and perennial species indicates that these materials are not dependable. Paraquat has been useful in renovating annual grass ranges in warm growing season areas, but has failed on the same species in cool season regions. Low rates of triazines, phenyl ureas, and uracils appear promising as aids in manipulating species without reseeding.

INTRODUCTION

Herbicides are being explored and used in the United States for improvement of grasslands. These uses include the killing of woody species on large acreages of land in many climate zones. Land thus treated for brush control may be reseeded after burning or left for improvement of native vegetation. The literature for brush control on range and pasture lands is voluminous and will not be reviewed as this is a widely known and accepted practice. The same can be said for the use of herbicides for the control or elimination of many poisonous and non-poisonous perennial herbacious weeds.

Interest has been shifting to the use of herbicides for the removal or suppression of all species present on land to be improved to permit seeding without tillage, or for control of weeds on tilled fields prior to seeding. Work is also underway to use residual herbicides for the removal of annual species to permit more rapid increase in vigor of perennials when coupled with improved grazing management.

Work reported or available for review in the United States is summarized.

METHODS AND MATERIALS

Experiment 1

Sprague et al. (7 & 8) report the results of studies undertaken in New Jersey from 1949 to 1960. Insofar as possible, standard procedures were employed when applying chemicals and tillage treatments. In most instances the sites were chosen on farms in areas of the State representing major problems. Sods were sometimes characteristic of the then overgrazed, stony, and infertile pastures in northern New Jersey. In other instances weedy sods were used on deeper soils. Where small plots were used for critical evaluations of chemicals and tillage treatments, uniform stands of seeded grasses were employed. In reporting each experiment in detail, the sod is described as to soil condition and species. Chemicals tested were in pounds active ingredient per acre applied in water with one-fourth percent nonionic wetting agent applied with a low gallonage sprayer using from 10 to 40 gallons of water per acre. Adapted species were seeded and fertilized to optimum requirements. Herbage yields were taken from harvested samples and botanical analyses made by hand separation. Experiments include use on sod of TCA compared with nonsprayed, TCA compared with plowing, and tillage following use of TCA. Several herbicide trials for chemically prepared seedbeds included comparisons of amitrole 1-8 lb/ac, dalapon 4-20 lb/ac, TCA 20-30 lb/ac, cacodylic acid 1-24 lb/ac, and mixtures of dalapon and amitrole or dalapon and cacodylic acid. This work reports the results of a number of research workers including Chase (1), Evard (2), and Kate (3).

Experiment 2

Work in Connecticut by Peters (6) was designed to determine whether non-tillage establishment of improved pasture species could be accomplished with the aid of herbicides on the stony non-tillable areas of this region. Experiments were started in 1951. All experiments employed a replicated randomized block design with herbicides applied to non-tillable sod in 40 gallons of water per acre. All forage seedings were handcast with no attempt to cover the seed except in one instance. Herbicides tested included sodium chlorate, ammonium thiocyanate, TCA, monuron, chloropropham, endothal, phytotoxic oils, oil-fortified TCA and DNBP, amitrole, and dalapon. A wide variety of dosages were compared. Sod species included bentgrass (*Agrostis tenuis*), poverty grass (*Danthonia spicata*), sweet vernal (*Anthoxanthum odoratum*), and red fescue (*Festuca rubra*).

Experiment 3

In order to determine the sensitivity of various sods to herbicides, work at Oregon State University was undertaken on planted sods of Merion Kentucky bluegrass, Lincoln Smooth Brome, Perennial ryegrass, chewingsfescue, highland bentgrass, cocksfoot, meadow foxtail, tall oatgrass, and tall fescue. Each sod was planted in the spring of 1953. The herbicide treatments for sod killing compared applications made in the autumn of 1955 with early spring treatments in 1956. The kill of sod was evaluated at the beginning of the summer dry season in late June. The herbicides used were dalapon at rates of 5, 10, and 30 lb/ac, amitrole at 2,12, and 24 lb/ac and chloropropham at 4 and 8 lb/ac.

Experiment 4

Work conducted by McKell and Kay (5) on annual range predominantly medusahead Elymus caput-medusae has been devoted to the use of paraquat prior to sod seeding of perennials, primarily hardinggrass. Various dosages of paraquat cation with wetting agent have been tested with different band widths ahead of the seeder.

Experiment 5

Studies by Furtick, Turner, and Gould (unpublished data) at Oregon State University on dryland annual grass range dominated by medusahead (Elymus caput-medusae) and annual brome (Bromus tectorum) have involved use of paraquat and mixtures of amitrole-T with esters of 2,4-D for complete vegetation control prior to non-tillage seeding of dryland grasses and lucerne. All applications were made after autumn rainfall had germinated the annual grasses. The dates of application ranged between November and March. Seeding was accomplished during the winter or early spring. Comparison was made with tillage treatments and no treatments other than seeding. All applications were broadcast over the entire plot. Rates used for paraquat ranged from 1/2 lb/ac to 3 lb/ac. Amitrole was used at 1 or 2 lb/ac with 1 or 2 lb/ac of 2,4-D esters.

Experiment 6

Kay (4) reports studies with paraquat as a selective treatment to remove annual grasses from annual California ranges seeded with the annual clovers, rose clover (Trifolium hirtum), and subclover (Trifolium subterraneum). The grasses sprayed were primarily medusahead (Elymus caput-medusae), foxtail fescue (Festuca megalura), and wild barley (Hordeum species). Paraquat was sprayed with a logarithmic sprayer at dosages of .20 lb/ac to 3.25 lb/ac. Applications were made on both seeded trials and on ranges where these clovers had severe competition from the unproductive or non-palatable annual grasses.

The applications were made at dates ranging from Nov. 20 to April 1. The clover varied from 4 trifoliate leaves to 4 inches tall. On the range experiments, sheep grazed all plots. Measurements were based on composition determined by a step-point method. The planted trials were evaluated by harvest of herbage.

Experiment 7

Several trials have been conducted on both seeded and non-seeded native ranges in Oregon to determine the effect of using residual herbicides to remove annual species from perennials. These trials have been conducted since 1959. Applications have been made broadcast at dates ranging from Oct. 1 - April 1 on established perennial seedings dominated by unwanted annuals, primarily medusahead (Elymus caput-medusae) and annual brome (Bromus tectorum) The same treatments have been compared on natural ranges in various stages of deterioration from overgrazing. The trials have been protected from grazing to determine speed of recovery of perennials where annuals were removed compared with non-treated. The herbicides used have included simazine, atrazine, prometryne, monuron, diuron, isocil, bromacil, amitrole, paraquat, and dalapon. The dosages of the triazines, phenyl ureas, and uracils ranged from .8 to 3.2 lb/ac; dalapon, amitrole, and paraquat ranged from 1-3 lb/ac. The results have been determined by sampling for yield and composition.

EXPERIMENTAL RESULTS

Experiment 1

Sprague et al. (8) gives a summary of results from all experiments in addition to the more detailed presentation for individual experiments. His overall summary is abstracted as follows:

1. Seedbed preparation with herbicides and minimum tillage proved to be easier, quicker, and cheaper than most conventional tillage methods.

2. TCA was used to demonstrate the principle of pasture seedbed preparation with herbicides, but its cost, corrosive character and residue left in the soil make it impractical for farmer use.

3. Sodium arsenite applied at the rate of 25 pounds per acre gave immediate top kill, but regrowth from rhizomes was rapid.

4. Dalapon at 8 pounds per acre will reduce a live bluegrass sod to a dead mulch during the growing season in New Jersey. Dalapon often leaves troublesome broad-leaved weeds unkilled in most pastures unless another herbicide is added.

5. The residue left in the soil when TCA, dalapon, or 2,4-D is used at adequate rates necessitates a long delay between spraying and seeding to grass-legume mixtures.

6. A mixture of dalapon (4 pounds) and amitrole (1 pound) killed most pasture sods, and a delay of 2 weeks plus some rainfall are required before grass-legume mixtures can be safely seeded.

7. A mixture of 4 pounds of dalapon and 2 pounds of cacodylic acid kills most pasture sods, and seedings are safely made 2 weeks after treatment.

8. Cacodylic acid, at rates of up to 12 pounds per acre, was safely applied within one hour of seeding without effect on seedlings. Split application reduced the amount of chemical required.

9. Amitrole at 4 pounds killed all plants in most pasture sods.

10. Cocksfoot was more tolerant of cacodylic acid residue than other herbicides.

11. Grazing old pastures as closely as possible before treatment enhances the effectiveness of the herbicides and makes tillage easier.

12. Date of planting determines when herbicides should be applied. Choice of chemical will be based on season, and weedy plants to be killed.

13. During the winter there is less erosion on a dead mulch seedbed than on one that has been plowed. Broadcast seedings of small seeded legumes on dead sod in late winter become much better established than similar seedings on fall plowed ground.

14. Perennial forages last several years longer when their seedbeds are prepared with herbicides rather than plows.

Experiment 2

Of the many chemicals tested, dalapon has proven most satisfactory for subduing established sod grasses. Chloropropham and monuron are needed at uneconomically high rates and monuron leaves long term residues.

Satisfactory sod control has been obtained with dalapon-amitrole mixtures applied in the spring, late summer, and late fall. The fall treatment has the advantage of allowing time for disappearance of the dalapon residues by seeding time in the spring.

Under Connecticut conditions, 7.5-10 pounds per acre of dalapon will usually subdue an established sod long enough to permit grass and legume establishment.

The addition of 2-4 pounds per acre of amitrole with dalapon will decrease the amount of dalapon required and give a measure of control of forbs present.

Application of the herbicide in the late fall on closely grazed sod followed by broadcast "frost crack" seeding of herbage species early the following spring gave best results.

The persistance of vegetatively propagated forbs continues to be a frequent problem when no supplemental tillage is employed.

Experiment 3

The results of this trial indicate that the selection of the proper chemical is determined by the species of the sod crop. Some species are most sensitive to dalapon while others are most resistant. The same may be said for amitrole. The period of the year in which a species is most sensitive varies between chemicals. Different species may vary in the time of the year they are most sensitive to the same herbicide. This makes the use of either dalapon or amitrole on mixed sods most difficult. Chloropropham was not satisfactory. These results are summarized in Table I.

Table 1.

A comparison of toxicity between autumn and spring applied herbicides on ten planted sods

Sod species	Percent kill of sod by herbicide, dosage, and time of treatment															
	Dalapon						Amitrole						Chloropropham			
	5 lb/ac		10 lb/ac		30 lb/ac		2 lb/ac		12 lb/ac		24 lb/ac		4 lb/ac		8 lb/ac	
	Aut.	Sp.	Aut.	Sp.	Aut.	Sp.	Aut.	Sp.	Aut.	Sp.	Aut.	Sp.	Aut.	Sp.	Aut.	Sp.
Merion Kentucky bluegrass	75	62	80	65	95	82	88	90	100	100	100	100	25	35	30	48
Lincoln Smooth brome	98	95	100	98	100	100	35	70	100	100	100	100	10	8	10	38
Perennial ryegrass	100	85	100	98	100	100	0	30	100	100	100	100	40	52	62	48
Chewings fescue	22	42	48	50	70	68	0	0	30	8	65	25	68	58	70	82
Highland bentgrass	12	75	22	80	80	92	0	0	0	2	42	5	0	0	0	0
Cocksfoot	100	92	100	100	100	100	15	20	100	95	100	100	0	0	0	0
Meadow Foxtail	45	98	68	92	100	100	0	0	50	20	30	40	0	0	0	2
Tulatin oatgrass	80	98	55	100	70	100	0	0	30	40	40	95	0	0	0	0
Red fescue	15	22	22	32	30	32	0	0	28	10	75	48	2	28	8	2
Tall fescue	10	10	18	12	35	38	0	8	70	70	75	78	12	52	8	48

Experiment 4

Trials with paraquat on ranges in California to kill annual grasses prior to reseeding of perennials such as hardinggrass indicated suitable kill of the annual species could be accomplished after complete germination of the annual grass with treatments of 1/4 to 1/2 lb/ac with wetting agent added. Suitable establishment of perennials occurred when the spray band of killed annuals was 8 inches or wider. Bands less than this caused death of the young perennial grasses during the dry summer season typical of this region.

Experiment 5

Paraquat used during the cool season required for annual grass control in Oregon was ineffective for the control of medusahead. Rates of one pound cation or above gave kill of annual brome. Lower rates were not always effective. Amitrole-T and 2,4-D ester used in combination were very effective for kill of annual brome, but sometimes failed on medusahead. Where complete or nearly complete kill of annual grasses was achieved, dryland grasses or lucerne were readily established in favorable moisture years.

Experiment 6

The leaves of all species were scorched and the plants defoliated by paraquat application. The resistant species sprouted and continued to grow. This resulted in a delay in herbage production. However, total herbage production was not always reduced; in some instances it was increased slightly due to early weed control. Subclover and rose clover yields were not decreased by any rate or date of spraying. Ryegrass was only moderately resistant and was most resistant at the late dates of application.

In range tests, annual grasses were removed from subclover and hardinggrass at all three dates of application without damage.

Experiment 7

Both seeded and native species were initially adversely affected by treatments with dalapon, amitrole, or paraquat. The effect was only slight during late autumn, winter, or early spring treatment. The dalapon was satisfactory in control of medusahead only at the low rates of use. Paraquat was effective on annual brome but not medusahead. Amitrole was not satisfactory unless used with 2,4-D or other herbicides.

The most promising results were obtained with atrazine and the uracils. Although the phenyl ureas, simazine, and prometryne were safer on the perennial grasses and lucerne, annual grass control was not dependable under the low rainfall conditions of the test areas. Isocil was usually more damaging than bromacil, and both tended to be more severe on the perennials than atrazine with the exception of perennials in the genus Poa which have considerable tolerance to uracils, particularly bromacil.

The autumn treatments were the most selective, and generally superior for the control of annual grasses. The spring treatments usually were superior over a two year period because they preceded the summer dry conditions which characterize the region. They usually gave residual control of the annuals the following autumn, while autumn treatments which precede the rainy winter season often did not persist until the following autumn.

The yields of forage in this region appeared to be limited by available moisture as the total yield remained about constant for all treatments, but the distribution between perennial herbage and annual herbage depended on location and treatment.

Dosages of .8 - 1.6 lb/ac of atrazine or bromacil did not reduce total yields. The entire yield with these treatments was perennial herbage. At some locations more than half the herbage on the unsprayed was medusahead, which is not utilized as herbage. On severely deteriorated native grasslands, annuals produced as much as 90 percent of the herbage. Removal of annuals caused as much as a ten fold increase in individual plant herbage production.

Grazing observations indicated livestock sought out the treated places and would utilize them completely while using untreated mixed perennial and annual grass stands in the same field to a very limited extent.

DISCUSSION

Trials from various workers in the United States of America indicate that in the bluegrass (Poa pratensis) areas of the east, dalapon, amitrole, or the mixture of the two can be used very effectively for sod killing prior to reseeding to improved grass-legume mixtures. In areas with a wider range of species, both annual and perennial, these materials are not always satisfactory. Trials with paraquat for this purpose indicated satisfactory results in California under warmer climate conditions, but in the cool season rainfall areas of California and Oregon, this treatment was not satisfactory on the same species. Apparently temperature as it relates to growing or treating conditions is a major factor relating to effective use of paraquat.

A promising method of improving perennial herbage production in areas once perennial grasslands, but now dominated by annual grasses, was indicated by low dosage treatment with residual herbicides. The potential of their use needs much more study.

Studies in more humid areas than the trials reported indicated herbicides such as diuron applied in the fall could not only selectively remove undesirable annuals but also certain perennials such as Yorkshire fog. They open a whole new area of controlled ecology, similar to that accomplished with phenoxy herbicides.

Acknowledgements

The work reported includes trials conducted by M. A. Sprague and many of his colleagues, R. A. Peters, C. M. McKell, B. L. Kay, R. A. Turner, and W. L. Gould, in addition to the author.

References

1. CHASE, RICHARD W. (1960) An Evaluation of Factors Affecting the Use of Herbicides in Pasture Renovation. M. S. Thesis Rutgers - The State University of New Jersey.

2. EVRARD, T. O. (1958) Some of the Agronomic Aspects of Pasture Renovation Using Herbicides. M.S. Thesis Rutgers - The State University of New Jersey.

3. KATE, A. H. (1956) An Evaluation of Herbicides in Pasture Renovation. M. S. Thesis. Rutgers - The State University of New Jersey

4. KAY, B. L. (1964) Paraquat for Selective Control of Range Weeds. Weeds. 12:3

5. McKELL, C. M. and B. L. KAY. (1964) Chemical Fallow Aids Perennial Grass Establishment. California Agriculture.

6. PETERS, R. A. (1960) Observations on the Use of Herbicides for Renovation of Non-tillable Pastures. Proc. Northeastern Weed Control Conference. 14: 314-319.

7. SPRAGUE, M. A. (1952) The Substitution of Chemicals for Tillage in Pasture Renovation. Agronomy Journal 44: 405-409.

8. SPRAGUE, M. A., R. D. ILNICKI, R. J. ALDRICH, A. H. KATES, T. O. EVRARD, and R. W. CHOSE. Pasture Improvement and Seedbed Preparation with Herbicides Rutgers - New Jersey Agricultural Experiment Station: Bulletin #803.

ESTABLISHMENT OF LEGUMES IN OLD POA PRATENSIS L. SOD BY USE OF PARAQUAT AND STRIP-TILLAGE FOR SEEDBED PREPARATION

T. H. Taylor, J. M. England, R. E. Powell,
J. F. Freeman, C. K. Kline, and W. C. Templeton, Jr.

University of Kentucky, Lexington, Kentucky, USA

Summary Two field investigations were conducted during 1963-64 to explore the use of paraquat and strip-tillage as aids in establishing legumes in a P. pratensis sod. Paraquat applied at 1 lb/ac suppressed spring growth of grass to the same degree as higher rates, and grass recovery was better. Seedling stands of Trifolium pratense L. (red clover) were unaffected by 1, 2 or 4 lb/ac of paraquat while T. repens L. (white clover) stands were depressed by the 4-lb rate. Medicago sativa L. (alfalfa) stands were improved at all rates. Soil moisture loss from the top inch of soil was greatly reduced by treating the sod with paraquat. Alfalfa production in the establishment year was improved by strip-tillage, paraquat and supplemental water, each having a cumulative effect. On the other hand, production of the established grass-legume swards at the first harvest (13.5 months after sowing) was not improved by tillage or herbicide. Plots treated with 5 lb/ac of dalapon and seeded immediately to alfalfa were as productive as paraquat-treated plots.

INTRODUCTION

Encouraging advances are being made in grassland management through use of herbicides to suppress or destroy grassy vegetation during the establishment of more desirable species. Sprague et al. (1960-1963), Davies et al. (1960), Jones, J. (1962), Jones, L. (1962), Charles and Lewis (1962), Robinson and Cross (1963) and others have demonstrated the use of dalapon as an aid in establishing a new sward. Two of the principal shortcomings of dalapon, as pointed out by Elliott (1962), are: (1) slow action on existing grassy vegetation, and (2) residual effect on the seeded species. Paraquat, a newer herbicide than dalapon, is much faster acting on grasses and is deactivated on contact with soil. Work reported by Blackmore (1962), Jones, L. (1962), Douglas and McIlvenny (1962) and Charles and Lewis (1962) show that paraquat may be used successfully in many renovation situations to suppress grassy swards while more desirable species are becoming established.

The purposes of this study were: (1) to evaluate the herbicidal effects of paraquat when applied to an old P. pratensis sod, (2) to observe the behavior of different legume species seeded into the sod immediately after herbicide application, and (3) to compare herbicide-tillage combinations in seedbed preparation for the establishment of alfalfa.

METHOD AND MATERIALS

Two replicated experiments were established in the same field of 6-year-old P. pratensis sod in the spring of 1963 and observed through the first hay harvest of 1964. The land, classified Maury silt loam soil and considered highly productive,

The investigation reported in this paper (No. 64-3-65) is in connection with a project of the Kentucky Agricultural Experiment Station and is published with approval of the Director.

was surface limed and fertilized with phosphorus and potassium prior to seeding. Grass-weed vegetation was cut at approximately 3 inches above the soil surface and removed before seeding. Where herbicides were used surfactant X-77 was added to the spray solution at 0.5% v/v. After seeding the spring growth of grass and weeds was harvested above the legume seedlings in late April and mid-May. Grass-legume swards were harvested in late June and August. One hay harvest was taken the following May. Yield, botanical composition, legume-seedling stand and size were determined by accepted statistical methods of sampling. Treatment means were evaluated using Duncan's (1955) multiple range test with differences at the 5% level of probability considered meaningful.

Experiment I

Factorial treatments were: no herbicide; paraquat at 1, 2, and 4 lb/ac a.i.; no legume seed; 'Vernal' alfalfa at 12 lb of seed/ac; 'Kenland' red clover 10 lb; and 'Ladino' white clover 2 lb. Other treatments not included in the factorial arrangement were dalapon at 5 lb/ac a.e. with and without alfalfa. Plots were 7 by 20 ft in size. The herbicides were broadcast March 28 with a hand-operated boom sprayer which delivered 38 gal/ac and the plots were seeded immediately with a grain drill. The disc openers of the drill failed to cut through the above-ground sod mat; therefore, the seed were dropped on the surface of undisturbed soil. During a 4-week dry period in April the entire site was irrigated 3 times.

Experiment II

An experimental machine was built to strip-till the soil and apply herbicide either in bands or broadcast. Soil tilling was achieved at a ground speed of 1 mph by discs, rotating at 1200 rpm, which could be adjusted to till a strip (1) $\frac{1}{2}$ inch wide and 2 inches deep or (2) 2 inches wide and 2 inches deep. Individual plots were 5 rows wide, spaced 8 inches apart, and 20 ft in length. Alfalfa was planted with a clover drill fitted with disc openers. Paraquat was applied at 3.7 lb/ac a.i. on the areas actually treated. The entire site was passed over with a corrugated cultipacker after seeding on April 5. Table 4 lists the complete array of treatments. Irrigated plots received water equal to 75% of the evaporation loss from a Class A evaporation pan, less precipitation. Soil moisture was measured in the top inch of soil by the gravimetric method. Soil moisture measurements and irrigation extended over a period of 60 days after seeding.

RESULTS

Weather Conditions

Climatological data were recorded at a weather station approximately 600 feet from the experimental sites and are considered valid for these trials. Mean temperatures 1 inch below the soil surface of a P. pratensis sod were 47°F the last two weeks of March and 56° during April. The sod was actively growing at the time of herbicidal treatment and seeding. On March 31, 0.66 inch of precipitation occurred but only 0.23 fell in 3 showers from April 1 through April 28. Precipitation in May, June, July, and August was approximately normal for the region and soil moisture was thought to be adequate during that period for the establishment of grass-legume swards. However, in September and October precipitation was only 0.73 and 0.14 inch while evaporation from a Class A weather pan was 6.01 and 3.79 inches, respectively. During spring 1964, soil moisture and temperature were favorable for growth.

Experiment I

(a) Grass suppression and seedling size

The effects of paraquat on spring grass growth and legume-seedling size are shown in Table 1. Paraquat applied at 1, 2, and 4 lb/ac reduced grass growth sharply; however, the 1-lb dose was as effective as the 4-lb dose. Conversely, legume-seedling size 75 days after seeding was increased by herbicide. Treatment with either 1 or 2 lb/ac of paraquat resulted in larger plants than those on the non-treated plots. Plant size was further increased by 4 lb/ac of herbicide. No interaction between species and paraquat rates was observed; therefore, data for the 3 legume species were combined (Table 1). Red clover seedlings were larger than alfalfa or white clover seedlings.

Table 1

Effect of paraquat on grass growth 50 days after treatment and size of legume seedlings 75 days after sowing (Experiment I)

Paraquat lb/ac	Yield of Grass lb/ac	g/40 plants (legumes)
0	681 a*	8.7 c
1	172 b	16.5 b
2	97 b	19.4 b
4	78 b	23.7 a

*Means in the same column with a common letter do not differ at the 5% level of probability, Duncan (1955).

Seedling injury from paraquat was visible after emergence only if the young plant came in contact with the treated dead grass. Legume leaves touching the grass browned along the margin and had a scorched appearance. The green of affected leaves was of a lighter hue than that of normal leaves White clover appeared to be most affected, red clover intermediate and alfalfa least. Apparently the dead grass held paraquat active. The paraquat-affected legume seedlings were stunted for 4 to 6 weeks after planting, but recovered thereafter and grew in a normal manner. Alfalfa seedlings on the dalapon plots appeared stunted for a longer period but also recovered.

From planting through the 2nd grass harvest, May 17, the sward was relatively free of weeds except for a thin stand of Allium vineale L. (wild garlic) which was stunted by both herbicides.

(b) Legume seedling stands

Seedling-stand data 54 days after seeding are given in Table 2. A species x

Table 2

Effect of paraquat on legume stands 54 days after treatment (Experiment I)

Paraquat lb/ac	Plants/ft^2 Alfalfa	Red clover	White clover
0	19 cde*	26 abc	18 de
1	29 a	25 abcd	20 bcd
2	27 ab	28 a	19 cde
4	28 a	23 abcd	12 e

*Means with a common letter do not differ at the 5% level of probability.

herbicide interaction was observed; hence, the means for the interaction are shown. Alfalfa stands were improved by herbicide application. Red and white clover stands were as high on the non-treated as on the treated plots. White clover stands were higher with the 1-lb than with the 4-lb treatment, indicating that the higher rate of paraquat may be phytotoxic to this species. Alfalfa stands on the dalapon plots (not shown in Table 2) were 25 plants/ft^2 which compares favorably with paraquat-treated plots.

(c) Total sward yield

An interaction of species x herbicide rates occurred in the total sward, legume, grass and weed yields. Means are given in Table 3.

Table 3

Dry matter yields of grass-legume-weed swards for combined 1 July and 15 August harvests (Experiment I)

Paraquat lb/ac	No seed	Alfalfa	Red clover	White clover
		Total sward yield, lb/ac		
0	1409 f*	2138 ef	6560 a	3259 d
1	2012 ef	3670 cd	6871 a	3304 d
2	2443 e	4314 bc	6593 a	3418 d
4	2210 ef	4614 b	6287 a	3753 cd
		Legume yield, lb/ac		
0	------	1019 d*	5822 a	1829 cd
1	------	2314 c	6323 a	1784 cd
2	------	2659 bc	6197 a	1637 cd
4	------	3313 b	5786 a	857 d
		Grass yield, lb/ac		
0	1106 a*	881 abcd	615 bcdefg	857 abcd
1	339 efgh	1010 ab	492 defgh	1064 a
2	555 cdefgh	923 abc	222 gh	746 abcde
4	273 fgh	186 gh	75 h	282 fgh
		Weed yield, lb/ac		
0	303 ef*	216 e	123 f	573 def
1	1673 bc	342 ef	57 f	453 def
2	1850 b	732 def	174 f	1037 cde
4	1937 b	1115 cd	426 def	2617 a

*Means with a common letter do not differ at the 5% level of probability.

Red clover was highest yielding. Production on the red and white clover plots was relatively unaffected by paraquat. Alfalfa responded favorably to paraquat treatment, with plots treated at the 4-lb dose being higher yielding than those of the 1-lb dose.

(d) Legume yield

Red clover was more productive than alfalfa or white clover and was unaffected by herbicidal treatment (Table 3). White clover yields were similar on the no-herbicide and treated plots, with a trend toward lower production on the 4-lb paraquat plots. Alfalfa production was directly related to dose of herbicide. Plots treated with 4 lb of paraquat were higher yielding than plots receiving 1 lb. The 2-lb dose was intermediate. These data indicate that the legumes made a major contribution to total sward yield.

(e) Grass yield

In a general way, grass yield was related to dose of paraquat applied at seeding time. Grass production was lower at the 4-lb dose than at the 1-lb dose or with no herbicide. Other factors such as legume and/or weed competition and release of nitrogen by associated legumes probably affected grass yields. These influences may account in part for overlapping of the statistical rankings of the means.

(f) Weed yield

Sida spinosa L. (prickly sida) was the major weed present in the yield on July 1; however, Digitaria spp. (crabgrass) were the dominant weeds in the August harvest. Weed yields were related to the density of the grass and/or grass-legume stands. Generally, the denser the forage-crop stands, the lower the weed yields (Table 3). The highest weed yield was observed on plots treated with 4 lb of paraquat and seeded to white clover. Next highest yields were observed on the no-seed plots treated with 1, 2, and 4 lb of paraquat. Apparently, this old sod land contained a very high population of viable prickly sida and crabgrass seed which germinated, became established and made luxuriant growth where growing space was available.

Plots treated with dalapon and not seeded were extremely weedy (2979 lb/ac) with only a trace of grass present. Dalapon plots seeded to alfalfa were less weedy and the alfalfa content, 2205 lb/ac, compared very favorably with 2314 lb/ac on the 1-lb paraquat plots.

(g) Spring yield of the established swards

The vegetation was harvested May 19, 1964. An interaction of species x herbicide dose occurred in the total sward yield but not in the grass or legume component yields; hence, the arrangement of the data in Table 4. Weeds consisting of wild garlic, Plantago spp. (plantain) and Taraxacum officinale Weber. (dandelion) were present but of minor importance except on the paraquat-treated-non-seeded and white clover plots (data not shown).

On a total-sward basis the alfalfa-grass mixture was highest yielding, red clover-grass intermediate and white clover-grass lowest. The sod treated with paraquat and not seeded was low yielding. Paraquat did not improve yields on the no-seed, alfalfa or red clover plots; however, plots treated with 1 lb of paraquat and seeded to white clover were higher yielding than the other white clover and the no-seed plots.

The legume component in the grass-legume swards was highest for alfalfa, intermediate for red clover and lowest for white clover (Table 4). Grass production was highest when the grass was grown in association with white clover, intermediate on plots not seeded with legumes and lowest when grown with alfalfa or red clover. Grass yield on an overall basis was inversely related to dose of paraquat.

Alfalfa production on the dalapon-treated plots was 3998 lb/ac with only a trace of grass or weeds in the sward.

Table 4

Dry matter yield at first harvest, 1964 (Experiment I)

Paraquat lb/ac	Total sward yield, lb/ac			
	No seed	Alfalfa	Red clover	White clover
0	1179 def*	4538 a	3292 b	1753 d
1	693 f	4104 a	3094 b	2333 c
2	648 f	4066 a	3031 b	1413 de
4	642 f	4312 a	3109 b	1116 ef

Sown species	Grass-legume associations, lb/ac		Paraquat lb/ac	Grass yield lb/ac
	Legume	Grass		
No legume	------	594 b †	0	840 a †
Alfalfa	3886 a †	336 c	1	762 a
Red clover	2725 b	336 c	2	507 b
White clover	264 c	1098 a	4	258 c

*Means with a common letter do not differ at the 5% level of probability.

† Means with a common letter within a column do not differ at the 5% level of probability.

Experiment II

(a) Soil moisture

The top 1-inch of soil contained 31.5% $\pm$ 2.33 moisture on the day of seeding. Irrigated plots were watered frequently with the aim that soil moisture should not become a limiting factor in seed germination and emergence. From seeding time to late April, soil moisture depletion was greatest on the tilled plots, intermediate on unirrigated sod and lowest on the broadcast-paraquat plots. On May 1, after late-April rains, soil moisture was the same on all treatments, but by May 5 moisture loss was greatest on the tilled plots, intermediate on unirrigated sod and lowest on the herbicide-treated plots. Soil moisture content was lower on irrigated than on paraquat-treated plots on May 5, but by May 9 after water was added to the irrigated plots, these two treatments were the same in soil moisture. Following rains on May 13 and 20 soil moisture was the same for all treatments; however, by May 24 the same relationship prevailed as on May 5.

(b) Grass suppression by tillage and/or paraquat

The grass-weed vegetation was harvested above the legume seedlings twice by May 12 and yields are shown in Table 5. Weeds were of minor importance, but some wild garlic and Trifolium agrarium L. (hop clover) plants were present in the swards. Grass yields were low in general and were improved only moderately by the addition of water, indicating the low level of nitrogen in the old sod. Paraquat, either banded over the legume rows or broadcast, suppressed grass growth more than strip-tilling at $\frac{1}{2}$-inch ($T\frac{1}{2}$). Strip-tilling a band 2 inches wide (T_2) suppressed grass growth to about the same degree as applying paraquat in 2-inch bands (P_2). On paraquat-tillage plots the grass was unaffected on either side of the tilled strip, indicating that paraquat was deactivated by soil thrown by the rotating discs.

(c) Alfalfa seedling stands

Stands determined 28 and 42 days after sowing are shown in Table 5. The May 3 count reflects the dry condition that occurred during April. In general stands were higher on irrigated than on non-irrigated plots. Some mulching effect in terms of increased seedling stands was observed on the paraquat-broadcast treatment.

By May 17, date of the second count, 3.82 inches of precipitation had fallen on the experimental area. Treatment differences in stands were not significant due to large within-treatment variation. From May 3 to May 17 stands increased on the non-irrigated plots from a low of 2.7 plants/ft^2 to a high of 19.1, indicating that many of the seed remained viable through the drought period in April. Little or no stand increases were observed on the irrigated plots.

(d) Alfalfa seedling size

The shoot weights of alfalfa seedlings 68 days after sowing are shown in Table 5. Seedling size was increased by the addition of water; however, some effects of tillage and herbicide were apparent. Plants grown on plots treated with paraquat-broadcast or strip-tilled 2 by 2 inches were larger than plants grown on undisturbed sod, while plants on plots strip-tilled $\frac{1}{2}$ by 2 inches or band-sprayed with paraquat were intermediate in size. The cumulative effects of tillage, herbicide and irrigation were clearly demonstrated on plots strip-tilled, band-sprayed and irrigated ($T\frac{1}{2}$-P_4-I).

Table 5

Grass suppression, seedling stands (28 and 42 days after sowing) and seedling size (68 days after sowing) as affected by different seedbed preparations (Experiment II)

Seedbed treatment	Grass yield to 12 May lb/ac	Legume stands seedlings/ft^2 3 May	17 May	Legume seedling size g/50 plants 12 June
Sod seeded (O-S)	273 ab*	2.4 e	13.3 NS†	1.17 d
Sod till. $\frac{1}{2}$ x 2 in. ($T\frac{1}{2}$)	220 bc	12.5 cde	15.2	2.54 cd
Sod till. 2 x 2 in. (T_2)	146 de	4.8 de	23.9	3.17 c
Paraquat 2-in. band (P_2)	116 def	9.1 de	17.9	3.26 c
Paraquat 4-in. band (P_4)	39 f	6.8 de	18.5	2.79 cd
Paraquat broadcast (P_{bc})	0 -	14.2 bcd	24.5	5.35 bc
$T\frac{1}{2}$-P_2	156 cd	11.6 de	22.6	3.41 c
$T\frac{1}{2}$-P_4	69 ef	14.2 bcd	23.3	5.12 bc
$T\frac{1}{2}$-P_{bc}	51 f	12.2 de	21.3	4.57 bc
Sod seeded irr. (O-S-I)	331 a	11.2 de	14.9	4.92 bc
$T\frac{1}{2}$-I	276 ab	25.0 ab	20.9	11.22 ab
P_4-I	36 f	23.4 abc	22.3	9.80 ab
$T\frac{1}{2}$-P_4-I	134 de	30.2 a	31.0	13.88 a

*Means with a common letter within a column do not differ at the 5% level of probability

†Means were not statistically different.

(e) Yields for establishment year

Yields of the grass-legume swards harvested July 9 and August 20 were combined and the data are shown in Table 6. In general total sward yields were related to tillage, herbicide and irrigation.

Grass yields were lower than legume yields and in some cases lower than weed yields (Table 6). Grass growth was suppressed by tillage and herbicide early in the spring, but by late summer the suppression was much less evident except for treatments P_{bc} and P_4-I. In many cases grass yields were as high in the grass-legume swards as in the unseeded sod.

Legume yields were related to grass suppression at seeding time and to irrigation. In general, alfalfa yields on unirrigated plots were lowest for treatments that suppressed the grass least (O-S and $T\frac{1}{2}$) and highest on treatments that suppressed the grass most. Plots seeded and irrigated (O-S-I) were as high yielding as plots on which the grass had been severely suppressed by tillage or herbicide. These data indicate that water may substitute for tillage or herbicide in legume establishment (O-S I vs. T_2 and P_{bc}); also, paraquat may be substituted for tillage (P_2 vs. T_2) as shown in Table 6.

Weed yields were directly related to degree of grass suppression in the spring. Digitaria spp. were the dominant weeds at both harvests. Weed content in the cut herbage was 246 lb/ac for the sod-seeded treatment and 1594 lb for paraquat broadcast and seeded with alfalfa. Apparently, a grassy sward in the spring and early summer suppressed the establishment of weeds more than did excellent stands of young alfalfa later in the season.

(f) Yields of first hay harvest of established stands

Dry-matter production of the 13.5-month-old stands is shown in Table 6. Except for the unseeded plots (0) the grass-legume associations were almost free of weeds. Hence, weed yields are not shown. The grass-legume swards were dominated by alfalfa and were 7 to 8 times as productive as the unseeded sod. Little or no relationship was apparent between the amount of grass suppression by tillage or herbicide at seeding time and total sward yields the following spring. Moreover, the 1964 grass yields were the same for all treatments. On a comparative basis some of the higher yielding plots ($T\frac{1}{2}$-I, P_4-I and $T\frac{1}{2}$-P_4-I) during the seedling year were lower ranking in yields the following spring.

DISCUSSION

Under the conditions of these experiments it is evident that strip-tillage or herbicidal treatment did not significantly improve legume establishment, especially if the appraisal is rendered on spring production of the established stands. On the other hand, sowing red clover or alfalfa into the old sod, regardless of method employed, improved production 4-fold or more. Interpretation of these results requires that several features of the experiments be kept in mind. First, the soil, Maury silt loam, is highly productive and had been well limed and fertilized with phosphorus and potassium prior to seeding. Second, available nitrogen for grass growth was low, as evidenced by the amount of top growth of the untreated sod. Third, the legumes were seeded at a time when they were most likely to succeed. Finally, grass-weed growth was removed twice above the legume seedlings, and legume plants were harvested twice at appropriate stages of growth. Also, supplementary water during the critical period of germination and emergence in Experiment I enhanced stand establishment, especially for the clovers.

Table 6

Dry matter production establishment year and first hay harvest of following year (Experiment II)

Seedbed Treatment	9 July and 20 Aug. harvests combined 1963, lb/ac.				19 May harvest 1964*, lb/ac		
	Total	Grass	Alfalfa	Weeds	Total	Grass	Alfalfa
Sod unseeded (0)	798 d†	564 ab	----	114 d	516 d	312 NS††	----
Sod seeded (0-S)	1566 d	366 bcd	792 f	246 cd	3577 abc	288	3235 b
Sod till. ½ x 2 in. ($T_{\frac{1}{2}}$)	1644 d	408 abcd	918 f	213 cd	3760 abc	261	3424 ab
Sod till. 2 x 2 in. (T_2)	2866 c	492 abc	1933 cde	336 cd	4024 ab	288	3697 ab
Paraquat 2-in. band (P_2)	3436 bc	483 abc	1903 cde	714 bc	3742 abc	132	3571 ab
Paraquat 4-in. band (P_4)	2808 c	585 ab	1368 ef	786 bc	4126 a	165	3961 a
Paraquat broadcast (P_{bc})	4150 ab	156 d	2383 bcd	1594 a	3436 bc	258	3121 b
$T_{\frac{1}{2}}$-P_2	2841 c	654 ab	1578 def	465 cd	3781 abc	267	3514 ab
$T_{\frac{1}{2}}$-P_4	3211 bc	594 ab	2047 cde	570 bcd	3817 abc	135	3667 ab
$T_{\frac{1}{2}}$-P_{bc}	3598 bc	567 ab	1935 cde	1020 b	3475 bc	228	3229 b
Sod seeded irr. (0-S-I)	3250 bc	456 abcd	2254 bcd	132 d	3697 abc	258	3421 ab
$T_{\frac{1}{2}}$-I	4216 ab	540 abc	2866 ab	243 cd	3418 bc	243	3175 b
P_4-I	4000 ab	282 cd	2647 bc	690 bcd	3496 bc	144	3349 ab
$T_{\frac{1}{2}}$-P_4-I	4895 a	702 a	3427 a	462 cd	3403 c	327	3043 a

*Weeds were of very minor importance in this harvest and are not shown.

†Means with a common letter within a column do not differ at the 5% level of probability.

††Means were not statistically different.

With a denser sod, more available nitrogen to stimulate grass growth or failure to remove grass-weed growth above young legume seedlings treatment effects would likely be different from those observed in these trials.

Low yields of the established white clover swards were due, in large measure, to stand losses caused by the extended drought during September and October.

England (1963) and others have shown that alfalfa is more tolerant of dalapon than red and white clovers; therefore, the possibility exists that an alfalfa seeding could be done at the time of dalapon application. Results of the dalapon treatment (5 lb/ac and seeded immediately) further substantiate this possibility. The fact that only a trace of P. pratensis survived this treatment would suggest that a dose lower than 5 lb should be used. Furthermore, a lower dose would be less likely to injure alfalfa. In many circumstances, considerable advantage may be realized by seeding a legume at the time of herbicide application. Both may be done in one operation, reducing cost, and the legumes may have an improved likelihood of establishment.

Elliott (1962) suggested that with an appropriate herbicide little to no cultivation should be required in establishing new species in old grassland swards. The results of these studies fully support his thesis. Surface cultivation of an old sod enhances weed seed germination and plant establishment; furthermore, soil moisture near the surface may be lost at a more rapid rate than in a non-tilled soil. Certainly these side effects of tillage are undesirable for the establishment of seeded species. One possible route around these two tillage effects might be to band the herbicide over the seeded row as Blackmore (1962) did, leaving a strip of undisturbed sod between the rows, use a tillage-seeder machine that would prepare a very narrow seedbed slit ($\frac{1}{4}$ x $\frac{1}{4}$ inches), place and firm the seed in the bottom of the slit.

One of the weaknesses of these reseeding trials and of many reported in the literature is that seedbed cultivation, seed metering the placement and herbicidal application have too often been limited to a few conventional on-the-farm implements which are available to the researcher. New tools must be designed so that the ecologist may examine a wider spectrum of possibilities. Herbicides yet to be discovered and grassland tools as yet undesigned are some of the unfinished business of grassland researchers.

Acknowledgments

Particular thanks are due to the Agricultural Engineering Department for building the tiller-sprayer device and to the California Chemical Company for financial assistance.

References

Blackmore, L.W. (1962). Band spraying: a new overdrilling technique. N.Z.J. Agric. 104, 13-19.

Charles, A.H. (1962). Pasture establishment by surface-sowing methods. Herb. Abstr. 32, 175-181.

Charles, A.H. and Lewis, J. (1962). Observations on the use of herbicides on grasslands. Proc. 6th Brit. Weed Control. Conf. 1, 75-83.

Davies, G.C. et al. (1960). Hill pasture improvement with dalapon. Proc. 5th Brit. Weed Control. Conf. 157-164.

Douglas, G., and McIlvenny (1962). The use of paraquat as a sward-killer in the improvement of hill communities and lowland pastures. Proc. 6th Brit. Weed Control. Conf. 1, 45-55.

Duncan, D. B. (1955). Multiple range and multiple F tests. Biometrics 11, 1-42.

Elliott, J.G. (1962). Herbicides and surface reseeding. Agr. 68, 640-643.

England, J.M. (1963). The effects of paraquat, cacodylic acid and dalapon on Kentucky bluegrass sod and the establishment of legumes planted immediately after herbicidal application. Thesis U. of Ky. Library.

Jones, J. (1962). Dalapon as an aid to sward renovation. Proc. 6th Brit. Weed Control. Conf. 1, 65-73.

Jones, L. (1962). Herbicides to aid pasture renovation. J. Brit. Grassl. Soc. 17, 85-86.

Robinson, G.S. and Cross, M.W. (1963). Successful chemical pasture establishment in Hawke's Bay. N.Z.J. Agric. 106, 209-213.

Sprague, M.A. (1960). Seedbed preparation and improvement of unplowable pastures using herbicides. Proc. 8th Int Grassl. Cong. 264-266.

Sprague, M.A. et al. (1962). Pasture improvement and seedbed preparation with herbicides. N.J. Agr. Exp. Stat. Bul. 803.

REVIEW OF PASTURE WEED CONTROL IN NEW ZEALAND

L. J. Matthews
Ruakura Agricultural Research Centre, Hamilton, New Zealand.

Summary. Herbicides are essential to farming economy. They have replaced cutting and grubbing for low fertility scrub weeds, and fallowing or cultivation for weed control alone is no longer an economic practice. They are forming a useful aid to cultivation by prior turf destruction and for control of difficult weeds prior to cultivation. An increasing use is as a substitute for cultivation for pasture renovation and renewal on land that can be cultivated and on land too steep for cultivation. They show promise in this direction for crop establishment without cultivation and back to pasture without cultivation.

INTRODUCTION

New Zealand has a temperate climate, with rainfall varying from 15 to over 200 in. per annum in agricultural areas. There are over 2000 soil types. Only 14.3 million acres out of the total of 43.4 million acres of agricultural land is under 19° slope or classified as being cultivable. New Zealand is almost entirely dependent on primary produce, mainly animal products, for exports. Clovers (Trifolium spp.) form the nitrogen factory, and high producing pastures are constituted largely of bred strains of ryegrasses (Lolium spp.) and clovers. Pasture production varies from under 1000 lb/ac dry matter in unimproved areas to 18,000 lb/ac dry matter in highly improved areas.

Aid to cultivation for pasture establishment

A developing use has been the control of difficult-to-kill weeds by herbicides, followed by cultivation. Agrostis spp., perennial Poa spp. and couch (Agropyron repens) are the main grasses controlled in this way. Little or no use is made of this technique for the control of rhizomatous broad-leaved perennials, such as Cirsium arvense.

In wet seasons, particularly with rotary hoeing rather than ploughing, paraquat is employed to destroy the turf. This facilitates cultivation, reducing the number of cuts required and minimising weed regrowth. This technique could be broadened to include low rainfall areas or places where the turf mat takes a considerable time to decompose. Prior destruction of the turf facilitates rotting, particularly in areas of low microbial content.

Aid to pasture establishment after cultivation

Low fertility areas. Scrub weeds, such as gorse (Ulex europaeus) and blackberry (Rubus spp.) may prove troublesome until the carrying capacity is raised from 1-2 to 3+ ewe equivalents to the acre. Spot application of 2,4,5-T has been successful. Overall application is damaging to clovers and results are poor due to ineffective foliage cover.

Picloran, either alone or in conjunction with 2,4,5-T, shows promise, but this chemical is lethal to clovers and this may rule out its use for pasture spraying, even as a spot application. Small residues of picloran in the soil may be lethal to clover for a period of twelve months or more.

Used as a spot application in newly establishing pastures, 1 lb/ac a.e. of 2,4,5-T is adequate. Apart from treatment of scrub weeds in waste areas this is the most satisfactory use of 2,4,5-T.

Areas of intermediate fertility. Ragwort (Senecio jacobaea) is one of the main problems. In new pastures no adequate control is known. Heavy rates of 2,4-DB (2 lb/ac a.e.) give some measure of control, but are doubtfully economical. Treatment of 12-months-old pasture is most effective, preferably as a spot application, as the rate of 2,4-D required (1 lb/ac a.e.) is damaging to clovers if used in early summer and autumn periods.

The control of weeds of intermediate fertility should largely be by raising productivity. In ragwort control the aim should be to spend one penny on herbicides to one shilling on other improvements of stocking, fencing, fertilising and insect control. If this is adopted, ragwort, apart from isolated plants, ceases to be a problem in two to three years. Without improvement the continued use of 2,4-D, because of its damaging nature to clover, has actually increased the incidence of ragwort.

High fertility areas. In the past reliance was placed on autumn rather than spring sowing, heavy rates of seeding and judicial stocking (quick on and off grazing) to control weeds. This practice was of limited success. Rhizomatous species (Cirsium arvense) and docks (Rumex spp.) and perennial buttercups (Ranunculus spp.) thrived under dairying conditions, and largely Cirsium arvense under sheep-grazing. The quicker establishing ryegrasses smother clovers, leading to imbalance of pastures that takes up to six or seven years to correct. MCPB (2,4-DB if Polygonums are present) has allowed a lighter seeding rate and pastures may be sown in either spring or autumn. The range of weeds controlled by MCPB is too narrow to make this compound wholly satisfactory.

Aid to pasture establishment without cultivation

Low fertility areas

Scrub weeds. An estimated 6 million acres of all flat land and land too steep to be cultivated are covered by scrub weeds. The approach of spraying, seeding and fertilising has led to much wastage of herbicide. A figure approaching 2 million gallons of 2,4,5-T (3.6 lb a.e. per gallon) has been applied to date. It is doubtful if there are a quarter of a million acres of productive pasture as a result. The main reason for failure is inadequate control with 2,4,5-T.

The soundest approach is oversowing, fertilising, fencing and mob-stocking, and treating regrowths in the second year pasture by spot application of 2,4,5-T. Used in this way 2,4,5-T at 1 lb/ac a.e. is sufficient.

Prior to management practices, the only sound use of herbicides is as a desiccating agent to induce a clean burn in areas of high rainfall or for out-of-season use in fire districts. The development of picloran may alter the situation, but it is still doubtful economics to control a large mass of vegetation with herbicides when the density may be removed by burning. Gorse and blackberry constitute the main problems. For other species, such as bracken fern (Pteridium aquilinum var. esculentum) and Spanish heath (Erica lusitanica) stocking, with oversowing and fertilising is regarded as adequate; prior burning is not often necessary.

The largest use of earial application has been for the control of scrub weeds. In general the fixed-wing plane has been as satisfactory as a helicopter; both have been inferior to ground spraying. Both aerial and ground spraying have been unsuccessful, except for young regrowth gorse.

Low fertility grasses. The most dominant weeds are low fertility grasses, Danthonia spp., Chewings fescue (Festuca rubra, var. fallax) and browntop (Agrostis tenuis). At least 10 million acres of these grasses occur, largely on unploughable hill country. Without clover, the production is under 2000 lb/ac dry matter per annum. With heavy fertilising and over-sowing of clovers the productivity may be increased to 3-4000 lb/ac dry matter per annum. This trend is slow, and if not fertilised annually production declines.In areas with no previous topdressing and short growing seasons, prior destruction of the turf with herbicides is doubtfully successful. Mixtures of dalapon/amitrole have too long a residual effect to guarantee success. Browntop is not adequately controlled by paraquat to enable sown species to establish free of interplant competition. Under such conditions the sown species may strike in the first season, but not until the second year are they sufficiently established to overcome inter-plant competition. Clovers may be established initially but tend to dominate and make grass establishment at a later date difficult. As yet there is no suitable additive to paraquat for checking clover. Amitrole, amitrole T, picloran, dicamba, 2,4,5-T, etc. have too long a residual effect in soil to guarantee success. Cacodylic acid is a doubtful candidate for pasture renovation.

Intermediate fertility grasses. With fertilising and oversowing of clovers, Danthonia and Chewings fescue are replaced by browntop, Yorkshire fog (Holcus lanatus), clover association. High producing ryegrass and cocksfoot (Dactylis glomerata) tend to come in slowly if at all.

Without the high producing species applied fertilisers are not used to greatest advantage. Aerial application of fertilisers, such a feature of New Zealand farming, has not been a complete success for this reason.

Paraquat used at rates of 3-4 oz/ac of a.i. reduces interplant competition sufficiently to allow the successful establishment of high producing grasses and clovers. Establishment is slower than with cultivation, but within a year of sowing the carrying capacity is increased markedly and equal production to that of flat land has been obtained.

Paraquat adequately controls Yorkshire fog and if ryegrass and cocksfoot are present these species recover. The check to browntop is not sufficient on cold faces and results are poor as a consequence. The check to flat weeds is insufficient, but with improved carrying capacity they are eliminated. The acreage treated to date, apart from *Nassella trichotoma*, is small but is increasing rapidly with the availability of paraquat in areas of 30 in. of rainfall per annum and above.

High fertility areas

After cropping, particularly crop establishment with paraquat, adequate clover is usually present. If this is checked (checked with paraquat is usually adequate) the area may be sown with grass. Surface germinating weeds such as barleygrass (*Hordeum murinum*), biannual thistles and regrowth docks, may prove troublesome. The ordinary weeds associated with cultivation and cropping (*Polygonums*, *Chenopodium* spp., *Amaranthus* spp., etc.) are not evident. The pasture establishes quickly and may be grazed within 6 to 8 weeks.

Pasture maintenance

Broad-leaved weeds of low and intermediate fertility have largely been dealt with under 'Pasture Establishment'.

High fertility weeds - broad-leaved. A number of weeds are suited to the very practices aimed at increasing production. The introduction of upright growing grasses allows more bare ground; the use of electric fences for break-feeding and consequent pugging, the inability of bred strains of grasses to withstand summer droughts in hot weather, the greater susceptibility of bred strains of grasses to insect attack, autumn-saved pastures for winter and spring utilisation, etc. have allowed docks, buttercups, some thistles, chickweed (*Stellaria media*) to infest dairy pastures. The main broad-leaved weeds of high producing sheep pastures are thistles and storksbill (*Erodium* spp.)

Undoubtedly the materials that should be employed most widely are MCPB and 2,4-DB (only for docks). Both MCPA and 2,4-D are too damaging to clovers to be considered except prior to clover growth in the spring and when clover is dominant during the mid-summer period. In spite of clover damage warnings carried on all labels of MCPA and 2,4-D containers, these materials are still being employed at the incorrect time. 2-chloro-2-oxobenzothiazolin-3-ylacetic acid has proved a specific for chickweed control in autumn-saved pastures, without significant clover damage.

The importance of selective weedkillers for high producing pastures cannot be over-estimated. High fertility weeds and loss of soil stability, allowing excess pugging, are claimed as two of the most important factors limiting ultimate production. The control of high fertility broad-leaved weeds is regarded as being adequate, except for mature docks in pastures.

__High fertility grass weeds.__ Several high fertility annual grasses, especially barleygrass, thrive under higher nitrogen levels than bred strains of grasses and clovers. Barleygrass is claimed to be New Zealand's worst weed, especially under sheep grazing. Seed remains viable for only one year, but in practice control is easy, eradication difficult. No material has shown sufficient selectivity to date, but dalapon and paraquat are the two most widely employed.

In high fertility pastures, with the control of broad-leaved weeds perennial low-producing grasses have become more evident. __Poa trivialis__, Yorkshire fog, __Agrostis__ species and tall fescue (__Festuca arundinacaea__) are often prevalent and under dairying may constitute up to 40 per cent of ground cover. If the concept that ryegrass/clover yields the highest production is accepted, then lower producing grasses may be classified as weed grasses. The control of these species is better with dalapon than paraquat, but the residual effect of dalapon is a disadvantage if oversowing must be practised. Clover is not adequately checked by paraquat and no suitable additive is known. Pasture renovation as yet is not widely practised, but should gain popularity in areas of over 30 in. rainfall and where paspalum (__Paspalum dilitatum__) is not dominant. To date no adequate control is known for this species.

DISCUSSION

Broadly, herbicide usage falls into three categories:

(a) As an aid to replace low fertility and intermediate fertility weeds;

(b) As an aid to pasture maintenance in high producing areas;

(c) As a substitute for cultivation.

It may be assumed that in time the use under category (a) will decline. Use in category (b) will increase as a result of decline in low fertility weeds. The control of high fertility weeds has become an accepted agricultural practice. The biggest increase in usage in the future will be as a substitute for cultivation, pasture renovation and renewal and crop establishment. In time this may be the major use of herbicides. The main advantages are:

(a) Only the undesirable species in a sward need be replaced.

(b) Topography does not limit the method, or physical factors such as the presence of logs, boulders and soil erosion.

(c) Less applied nutrients are required than after cultivation.

(d) A more balanced sward results, due to less disturbance of soil structure and microbial content.

(e) Less equipment is required than for cultivation.

(f) Cropping weeds, as such, are not troublesome.

The present disadvantages of the method are that herbicides with no residual effect in the soil are required; paraquat is not flexible enough to meet all demands. Poor control of rhizomatous species, and inadequate check to paspalum and clovers are its main disadvantages. It is also less selective on ryegrass and cocksfoot than dalapon. The principle is sound, but as yet the available herbicides are not sufficiently flexible.

Research Summary

SOME EXPERIENCES WITH SHORT-CIRCUITING CULTIVATION

M.W. Cross - G.S. Robinson

Massey University of Manawatu, New Zealand

Summary: Experiments and observations indicate that, following a total vegetative kill by herbicides, adequate nitrogen is essential for the successful establishment and growth of pastures or crops, broadcast or drilled into the dead sward.

Lack of nitrogen may also often be a limiting factor when overdrilling for pasture improvement or forage cropping without using herbicides.

Pasture Improvement by Overdrilling:

Experience with overdrilling for pasture renovation has emphasised the need for the suppression of the resident vegetation if the overdrilled species are to establish and flourish. This suppression can be achieved partially by removal of rank vegetation with a flail harvester, or better, by severe grazing with sheep, followed by the use of an overdrilling machine which leaves an open shallow furrow ($1\frac{1}{2}$" wide by $\frac{3}{4}$" deep) along which the seed and fertilizer are distributed evenly and are then covered by harrowing. The subsequent composition of the pasture will be dependent largely upon the ability of the introduced species to dominate the resident vegetation. To aid this, phosphate should always be sown with the seed, clover should be vigorous to supply nitrogen for the grasses, subsequent topdressing should supply adequate nutrients, and grazing management should favour the sown species. Although it is difficult, by management, to eliminate completely the undesired species, control of them can usually be achieved. (Robinson and Cross, 1960).

Pasture Establishment with Chemicals:

When the resident vegetation is killed by a chemical spray, all competition is eliminated and the introduced species have every opportunity of establishing, provided growth requirements (drainage or irrigation, fertility, etc) are fulfilled, and appropriate grazing management given. Competition may be afforded by freshly germinated weeds, hence where practicable the seed should be drilled into the sprayed sward and distributed uniformly to speed germination and establishment and to avoid bare patches. In this instance it is not necessary to remove a strip of vegetation along the row when drilling. Drilling the seed and fertilizer into the soil is sufficient.

In a pasture improvement trial on infertile hill country chemical spraying and overdrilling were compared. (Robinson and Cross, 1963). The chemical treatment, applied on 5 March 1960, comprised 3.7lb a.i. of dalapon plus 1lb a.i. of amitrole in 20 gals. water per acre. At the time of spraying, the pasture had recovered from a summer dry spell and was close grazed. Weather conditions for the next three weeks were mild and cloudy with some rain. A good kill was obtained and on 23 March, a grass seed mixture at 20lb/ac. and superphosphate at $3\frac{1}{2}$ cwt were broadcast over the trial area.

Although moisture conditions following sowing were excellent for the germination of this surface sown seed, establishment and subsequent growth for the next six months were disappointingly slow, especially on the shady faces. After this period however, vigour increased and when the area was grazed for the first time in November, 8 months after sowing, there was an excellent mixture of grasses and clovers covering both the sunny and shady faces. The time lag between sowing and the commencement of vigorous growth in the spring was ascribed mainly to the lack of nitrogen during the period before the decomposition of the killed resident vegetation.

The overdrilled area was sown the same day as the chemically treated area, at the same seed and fertilizer rates. It germinated and established rapidly and uniformly over the whole area but, though the clovers continued to make good growth, the grasses showed an obvious nitrogen deficiency. The area was grazed in July to control competition from the resident species, and again in November. By January 1961 there was an excellent cover of clover and an obvious response by the introduced grasses to the clover nitrogen, although they were not as vigorous as in the chemical area.

Stocking rates on both areas were the same during the following autumn and winter, and since then, the two areas have been grazed as one.

In this trial, overdrilling was as good as the chemical treatment from the increased stock carrying capacity viewpoint though the pasture still retained many of the original grasses. A botanical analysis completed in July 1962 was in line with expectations as a result of the treatments - the sown species dominant in the chemical area with some bare ground and weeds in evidence; the resident grasses persisting at a reduced level in the overdrilled area; very few introduced species in the control area although this had received 4 cwt of superphosphate in the previous 4 years and 2lb/ac. of aerially sown clover.

TABLE I

Botanical Analysis completed July, 1962

Mixture Sown and Percentage Ground Cover

Species	Sown Mixture lb/ac.	Chemically treated %	Overdrilled %	Control %
Per. Ryegrass	10	35.5	13	0
Cocksfoot	4	6	3	0
Crested Dogstail	2	1	6	2
White Clover	2	21	18	1.5
Red Clover	1	0	0	0
Subterranean Clover	1	1	4.5	0.5
Browntop		5	29.5	30
Danthonia		1	7.5	12
Other Species		19.5	13.5	42 *
Bare ground		10	5	12

*Including 21.5 percent of annual clovers.

Demonstration plots on soil of higher natural fertility initiated on 1 April 1964, have exhibited the same general pattern of poor initial growth following the use of paraquat sprayed over a run-out pasture at 1 pint and 2 pints per acre in 27 gals. water. One pint/acre proved insufficient for a total kill; two pints/acre gave a complete kill of resident vegetation. (Blackmore, 1964). A range of grasses and cereals drilled separately over both sprayed areas emerged within eight days and made good growth till about 3" high when all showed obvious nitrogen deficiency. Sulphate of ammonia at 1½ cwt/ac. was applied on 18 June 1964, to part of each spray treatment.

On the 1 pint/acre plots, the response to nitrogen was marked and sustained while the portion without nitrogen remained stunted and unthrifty and suffered competition from the residual resident vegetation. On the 2 pint/acre plots there was a response to nitrogen during the first six weeks after application, but by September the unfertilized portion had almost caught up and all of these plots were growing vigorously.

Forage Cropping with Herbicides:

In a two-year trial comparing the effects of various intensities of cultivation on yields of choumoellier and on soil nitrate levels it was found that herbicides alone prepared a suitable seed bed for cropping direct from pasture. (During et al. 1963). The chemical treatment was 15lb dalapon and 1½lb amitrole per acre in 36 gallons of water.

The yield of choumoellier from the chemical plots was equal to orthodox cultivation although soil nitrate levels were markedly different in the early stages. Spraying and ploughing were done on 23-26 September 1959 and the crop was drilled on 30 October. At this date soil nitrate levels were highest on the cultivated plots but 7 weeks later they were highest on the sprayed plots. It was concluded that cultivation had stimulated the breakdown of the large amount of plant material (roots and foliage) which was estimated at some 11-12,000lb D.M. per acre and that the soil nitrate levels were a reflection of the speed of decomposition. This early variation had no permanent effect on the crop in this instance although in an area with a colder and drier spring the rate of mineralisation of nitrogen following the use of herbicides might become so slow as to be critical to crop growth.

The trial was fed off in situ by sheep and cattle during the winter and similar treatments were repeated the following spring. In this instance, in the absence of any bulk of organic matter, the chemical treatment proved much inferior to orthodox cultivation. Orthodox cultivation again stimulated nitrate formation, as indicated by samples taken at sowing time, but six weeks later, nitrate levels were very low in all plots. Without artificial nitrogen, the yield from the cultivated plots was significantly higher. With 69lb of fertilizer nitrogen per acre the yield between treatments did not differ significantly but in both cases, this amount was insufficient to make up the difference between the supply of soil available nitrogen in the first and in the second year.

Conclusion:

Following a total vegetative kill with herbicides, in the absence of artificial nitrogen the growth of introduced grasses and clovers is poor and retarded until the dead plant material begins to decompose. This may take up to six months after an autumn sowing in a cold climate, but is followed by vigorous growth which can be sustained by proper grazing management and fertilizer application.

When overdrilling for pasture improvement on low fertility country, the clovers should be introduced first. After fertility has been raised, the grasses should be overdrilled in a separate operation.

Seedbed preparation with herbicides will produce as good a forage crop, without artificial nitrogen, as orthodox cultivation in the first year following a vigorous pasture. A second crop on the same ground will give poor results unless artificial nitrogen is applied.

Compared with orthodox cultivation the rate of mineralisation of soil nitrogen appears to be slower following the use of herbicides and may be more seriously retarded by lowered temperatures and lack of moisture. In the absence of large quantities of decomposing plant residue, cultivation will lead to a more ready supply of available nitrogen for subsequent crop growth.

References:

BLACKMORE, L.W.; (1964) Chemical Renovation of Pastures in Southern Hawkes Bay and Northern Wairarapa. N.Z. J.Agric. 108, 2, 122-135.

DURING, C.; ROBINSON, G.S.; CROSS, M.W. (1963) A study of the effects of Various Intensities of Cultivation on Yields of Choumoellier and on Soil Nitrate Levels. N.Z. J.Agric. Res. 6 293-302.

ROBINSON, G.S.; CROSS, M.W. (1960) Improvement of some New Zealand Grassland by Oversowing and Overdrilling. Proc 8th Int Grass Cong. 402-405.

ROBINSON, G.S.; CROSS, M.W. (1963) Successful Chemical Pasture Establishment in Hawke's Bay. N.Z. J.Agric. 106, 3, 209-213.

CHEMICAL ESTABLISHMENT AND RENOVATION
OF PASTURES IN SOUTHERN HAWKES BAY AND NORTHERN WAIRARAPA

L.W. BLACKMORE
Farm Advisory Officer, Department of Agriculture, Dannevirke, New Zealand

SUMMARY. A review is given of the paddocks established in new pasture and renovated with the aid of chemicals since 1958. The methods which have proved best for low, medium and higher fertility levels are then outlined. Following this various methods of sowing seed on chemically treated swards, the interactions of grass-killing chemicals fertilisers and lime, the effectiveness of paraquat, and finally the relationship between organic matter build-up and trace elements are discussed.

RESULTS OF PADDOCK TRIALS SINCE MARCH 1958

Pasture Establishment:

Following on preliminary experimental work in 1956 and 1957 the first all-air (spray, seed and fertiliser applied by air) hill country area was established in March 1958 using a fixed-winged aircraft. Since that time six steep paddocks totalling 94 acres have been aerially established. In addition three areas totalling 14 acres have been established by ground means. The chemicals used have been 5 lbs dalapon and 1 lb. amitrole (100% a.i.) per acre to give a blanket kill of grasses and flatweeds. All aerially established paddocks have been sprayed with 20 gallons of spray mixture per acre. All areas were autumn established. The average annual rainfalls for these areas ranged from 41 inches to 56 inches.

Of the nine swards sprayed seven were browntop (Agrostis tenuis) dominant but contained some perennial ryegrass (Lolium perenne); one contained approximately 50% browntop and other low fertility-demanding grasses, and the other approximately 30% browntop and 60% cocksfoot (Dactylis glomerata), perennial ryegrass and timothy (Phleum pratense). The clover varied from 0.5% to 15% of the surface area.

Space does not permit details of these areas. Suffice to state that the results varied from striking successes to comparative failures. Two outstandingly successful areas resulted in an increase from 1½ ewes to 9 ewes per acre in one case, and from one dry sheep to 2 acres to 3 ewes per acre in the other. Both were on steep country and the figures given are for stock wintered. Four areas gave substantial improvements in carrying capacity and feed quality. They were, however, rotationally grazed so that differences in carrying capacity cannot be given. Two areas gave fair results only. It is too early to assess the final area but it appears promising.

Poor results were in one instance due to the residual effects of chemicals in the soil resulting in the deaths of seedlings. Seedling deaths associated with unfavourable weather conditions over the winter period, and especially with insect pests (Oxycanus spps., Costyletra zealandica) during the late autumn and winter are other important reasons. Weed invasion in one instance necessitated spraying with a butyric hormone weedkiller.

Pasture Renovation:

Season 1963/64: The promising pasture renovation trials carried out with paraquat during 1961 and 1962 led nine local farmers to renovate paddocks of their own during the autumn of 1963. Three were dairy farmers, five fat lamb farmers and one a sheep and cattle breeder. This area of 41 acres was established aerially.

The amount of active ingredient (i.e. ion) ranged from 4 ozs to 8 ozs and the volume of water used from 11½ gallons to 45 gallons per acre. All areas had high annual rainfalls ranging from 50 inches to 60 inches per annum, but the autumn was exceptionally dry. In most cases grasses alone were oversown but small amounts of clover were included in three paddocks.

These renovations were characterised by clover dominance during the spring and early summer, the dark green colour of the foliage during the first year, the outstanding summer and early autumn growth, and greatly improved palatability revealed by obvious stock preferences for renovated pastures and the noticeably good quality in lambs.

The results of these trials have previously been described in detail (Blackmore 1964).

Season 1964/65: During the months of March to early June (autumn to early winter), 188 acres of pasture represented by nineteen different paddocks were renovated with paraquat in Southern Hawkes Bay and Northern Wairarapa while an equivalent area was renovated over the rest of the country. At the time of writing (September) it was too early to predict how successful these areas would be. However the relative success to-date of each paddock in my own territory has been assessed on the bases of the original kill, establishment of the sown species and vigour of the resulting pasture. On this basis the prospects are as follows:-

Very promising	= 4	Fairly promising	= 5
Promising	= 9	Doubtful	= 1

Of the nineteen areas renovated ten used 4 ozs ion per acre, three used 5 ozs to 6 ozs ion, while six used 8 ozs ion. It was obvious that two of the areas receiving 8 ozs ion. and one area using 6 ozs ion would have given better results with 4 ozs ion.

USE OF GRASS-KILLING CHEMICALS IN RELATION TO FERTILITY LEVELS

The level of fertility of the sward to be treated is a most important consideration in deciding on the best procedure to follow. In the following, fertility levels have been grouped into three broad classes:-

(1) Very low fertility swards virtually devoid of clovers and dominated by low fertility grasses

As there are no species worth saving in such swards the aim is to kill completely the existing species and re-establish an entirely new pasture in their place. Complete pasture renewal brought about in this way is in direct contrast to chemical renovation where the aim is to remove only the unwanted species.

We have found dalapon to be a better killer of our low fertility grasses than paraquat and a mixture of dalapon plus amitrole to be best where flat weeds and poor type clovers are also present. Spraying has been carried out in the autumn followed by seed-sowing after an appropriate spell for the residual effects to wear off (usually three weeks to a month).

Some very successful results have been achieved by this method but results are inclined to be variable. There are more risks involved than with renovating. The risks are associated with the necessity for late spraying in drier than average autumns linked with the need to wait for the residual effects of the chemicals to wear off before sowing the seed. Establishment of the sown species is usually very slow over the winter period and this exposes the area to greater damage by insects and other pests and to weed invasion. Seedling deaths are sometimes associated with adverse seedbed conditions due to cold weather, a virtually denuded surface, and a depressed fertility status associated with turf rotting. In a trial carried out in 1958 on a sprayed surface under cold ground conditions, a substantial improvement in establishment resulted where the pasture seed mixture was dusted with a fungicide.

For success the sward should be well controlled with stock during the summer and autumn prior to spraying and at the time of spraying should preferably be no more than 1 to 2 inches in height. Lime if required should be applied in adequate amount shortly after spraying but under very acid soil conditions it may be better to apply it well in advance of spraying. The area should be insect-proofed from the time the seed is sown and sprayed for weed control using butyric hormones if establishment is in any way threatened. Apart from this the area must be liberally treated with fertilisers during the first year.

Other approaches to the improvement of this type of sward are by oversowing accompanied by heavy topdressing, while for very tight swards the use of a moderate rate of dalapon to open up the sward to assist clover establishment could well be an advantage.

(2) Pastures which have been improved out of the rough through oversowing with clovers and topdressing, but consist of diminantly poor-type grasses.

There have been two approaches here. The first is to carry out a partial renovation in the early spring using 4 ozs to 6 ozs ion paraquat per acre to part kill and suppress the grasses in order to allow the clovers to spread. A thirty-acre steep hill country paddock is being sprayed by air this September to achieve such a result. The second approach is to attempt a complete renovation by using 8 ozs ion paraquat per acre in the autumn to eliminate the bulk of the inferior grasses and to replace these with good ones by oversowing. Two hill country paddocks totalling 60 acres have been renovated in this way by aircraft with promising results. A light rate of clover (1 lb white clover per acre), was sown in one paddock and none in the other.

(3) Pastures which have been substantially improved through oversowing, topdressing and good management and contain a fair proportion of good grasses; or those which have been previously cultivated but have

shown considerable deterioration.

Both trial and paddock results have indicated that there is wide scope for the use of paraquat under such circumstances. Comparatively low rates will often effect substantial changes in sward composition over relatively short periods. The underlying principle is to use the least amount of chemical that will achieve the desired result. Excessive rates inflict unnecessary damage on the pasture. This seriously delays recovery time and may not necessarily mean a better kill of the undesirable grasses, the kill of which is often partially dependent on the subsequent management of the sward.

Again there are two approaches. Where the object has been to increase the proportion of good grasses or introduce a new species the rates of paraquat which have given the best results range from 3 ozs ion. to 6 ozs ion. applied in the autumn the seed being broadcast over the area from one to three days afterwards. Investigations are in progress to see whether the spring is also a suitable time for renovation. The second approach is to apply not more than 2 ozs ion. paraquat during the main growing period from spring to summer with the object of inducing clover dominance for specific purposes such as for lamb fattening, improving the quality of hay, correcting clover/grass ratios or improving clover seed yields (Leonard 1964). Spectacular improvements in the clover contents of swards have been brought about in this way.

SEED SOWING METHODS.

(a) Broadcasting: This has been the main method used and has proved very satisfactory. The collapse of the killed vegetation, and the action of the wind, rain and earthworms, all tend to bring the sown seeds into close contact with the soil. However, good rains following sowing are essential for a quick strike. Where paraquat is used clover recovery will provide excellent cover and protection for establishing seedlings and no doubt has an important micro-climatic influence. Under very favourable conditions for growth clover may threaten to smother the establishing seedlings and should be controlled by on-and-off grazing with stock using as large numbers as possible.

(b) Treading seed in with stock: A trial was conducted in autumn 1957 to see if there was any advantage to be gained by treading in the seed after it had been broadcast over a sprayed surface. Part of the paddock was treated in this way using a mob of sheep and part left for comparison. In this instance treading appeared to have no advantage so far as strike and subsequent management were concerned. As pastures have typically been no longer than an inch at the time of spraying there has never been a problem of getting the seed to penetrate trash.

(c) Overdrilling*: In general it has been found better to broadcast rather than overdrill seed because of the improved spread. However, under certain conditions it is safer to place the seed into the soil. That is where rainfall following sowing is likely to be inadequate for a quick even strike or when sowing under cold ground conditions. The advantages of overdrilling are that the seed is placed in more direct contact with the soil assuring a greater continuity of moisture supply and closer contact with fertilisers while slow establishing species have a better chance of

* or sod-seeding

competing with clover recovery growth. Cross-drilling, that is drilling one way and then at an acute angle to the first drilling, has the advantage of improving surface cover.

(d) Overdrilling and Broadcasting in one operation: This has been done experimentally on a paraquat treated pasture with encouraging results. Because of the placement advantages associated with overdrilling the slow establishing grasses and half the clover were overdrilled with the fertiliser while the fast establishing species were broadcast without fertiliser. Excellent establishments of cocksfoot, timothy and red clover were obtained by overdrilling these species and broadcasting perennial and Ariki (long rotation type) ryegrasses.

(e) Overdrilling in narrow rows: Overdrilling in 3 inch or 4 inch rows would have all the advantages of both broadcasting and overdrilling. The advantages offering from chemical renovation techniques would no doubt warrant a careful look into such a possibility. Three-inch drills have been experimentally tried on a sprayed surface and gave a quick even strike of seed and excellent cover.

(f) Band-spraying: This technique was first used in March 1961 and has been previously described (Blackmore 1961). While it allows the introduction of grasses into swards otherwise too grassy to be successfully overdrilled, it has not taken on to-date. The reason for this is that for a slightly greater cost complete renovation can be achieved.

(g) Spray-seeding: Using the boom at the front of a vehicle and broadcasting the seed at the rear with suitable guards to protect both spray and seed. Tests are being conducted to see whether any loss in seed germination is more than compensated by a saving in time.

(h) Aerial sowing: Excellent spreads of seed have been obtained on chemically treated hill country areas using aircraft fitted with venturi-type distributors. The aircraft fly over the area twice markers being used to ensure good coverage. However, it is most important to know the pattern of distribution of seed and the effective swath width for each type of distributor and the conditions under which a good spread can be expected.

INTERACTIONS OF CHEMICALS, FERTILISERS AND LIME.

The application of grass-killing chemicals to a pasture initially induces a temporary deficiency of plant nutrients due to the increased food demands of the bacteria associated with turf rotting. The shortage of nutrients at this stage can in fact become so acute that the survival of both plants surviving spraying and oversown species may be at stake. This was clearly shown in an autumn established trial on country where very little previous topdressing had been done and no fertiliser was applied after spraying with paraquat. This resulted in a substantial proportion of the original clover, and virtually all of the oversown species failing to survive the winter. However, from the spring on the availability of nutrients obviously increases rapidly as a result of the breakdown of killed species, the accelerated nitrogen output brought about by clover dominance, and the breakdown of some of the accumulated soil organic matter. The proportion of the latter which can be broken down in this way varies widely with soil type (Jackman 1955).

An important function of lime applied to pastures is to promote the breakdown of accumulated organic matter thus increasing the availability of minerals. The following instances indicate that there is a close tie-up between the action of lime and grass-killing chemicals requiring further study. Two preliminary trials established in April 1963 have demonstrated the following:-

(1) In the first trial a marked response to lime occurred in the "no paraquat" treatment while there was no response to lime in the paraquat treatment. The lime was applied immediately after spraying which was done in the autumn.

(2) In the same trial marked molybdenum deficiency symptoms were observed in clover where no paraquat was used (which was confirmed by a marked response to molybdenum with the disappearance of the deficiency symptoms). By contrast no molybdenum deficiency symptoms were observed where paraquat was used.

It would appear therefore that lime may not be required on some New Zealand soils which normally respond to lime, when grass-killing chemicals are used. Where responses can be obtained, however, lime may be of great value especially where fertility is low. Where fertility is higher it may bring about a quicker return to grass dominance through the accelerated release of nitrogen.

(3) In a second trial on a different soil type a good response to lime was obtained both with and without paraquat.

EFFECTIVENESS OF PARAQUAT.

Trial work has shown that the effects of paraquat can be very variable. Some important factors causing this variability are the weather conditions experienced at and following spraying (especially light intensity, humidity, temperature); the length of the pasture leafage at spraying; the efficiency of spray coverage; the growth stage and vigour of the plant, the individual susceptibility of species; the rate of recovery of the sprayed pasture and the subsequent management. Once the reasons for variability are known we may be able to exercise more control over these factors and in some cases put the variability to some practical use. Examples are set down below:-

1) Light intensity: It has been observed that paraquat has much greater lethal effect on pasture species growing within the autumn and winter shade areas of shelter belts. In two paddocks renovated with paraquat in April 1964 practically a complete kill of the original sward species, including the clovers, occurred in the shade-affected areas whereas the recovery of the clovers and certain grasses was good in the remainder of the paddocks. Considerably reduced rates of paraquat are therefore desirable for such areas.

If suitable non-reactive agents that would absorb light, were mixed with paraquat spray then more consistent effects may be possible together with the need for reduced amounts of active ingredient. Trials are in progress using certain black dyes, rhodomine, and methylene blue while some of the thiosorbs which absorb ultra violet light may also be tried.

(2) Length of pasture at spraying: In a trial where pasture was mown to approximately $\frac{1}{4}$ inch in length, the kill of grasses was noticeably better than where it was mown to approximately 1 inch in height.

(3) Growth state and vigour of the plant: Both appear to have an important bearing on paraquat effectiveness. Observations and trial work show that grasses are more susceptible under the following circumstances:-

(a) During the early recovery stage after a dry summer and autumn and before they are fully recovered. Other factors such as insect damage or plant diseases by weakening plants may also increase susceptibility.

(b) Where the mineral status of the soil is inadequate. Attempting to chemically renovate pastures on such soils is to court trouble. While the kill is usually good, recovery of the clovers and establishment of the oversown species are characteristically slow.

(c) Where plant vigour is reduced by repeated hard grazing preparatory to spraying, thus reducing plant reserves.

Plants also vary in their susceptibility at various times of the year.

(4) The individual susceptibility of plants: Experimental work has shown legumes to be highly resistant to paraquat, cocksfoot and timothy fairly resistant, perennial ryegrass and browntop moderately susceptible and Yorkshire fog, Poa annua very susceptible.

(5) Rate of recovery of plants which survive spraying: Under favourable weather conditions quick recovery of the clovers tends to reduce the chances of survival of those grasses that have been weakened but not killed by the spray. This is due to shading mainly but also to the increased competition from the clovers for soil nutrients, and water if this is in short supply.

(6) Subsequent management: This can exert a marked influence on sward composition. If the pasture is allowed to remain relatively long after renovation, as is usually the case on a dairy farm, then the suppression of naturally low growing grasses previously affected by the spray is greatly increased. Where relatively low rates of paraquat have been applied during good growing conditions and the pasture has been "spelled" for clover growth (e.g. clover cropping for lamb fattening) surprisingly high grass kills have resulted.

ORGANIC MATTER BUILD-UP AND TRACE ELEMENTS

There would appear to be a close tie-up between the build-up of organic matter in soils and the availability of trace elements. If the proportion of minerals bound up in organic form (including the root mass) exceeds certain limits then mineral imbalance must result and affect the pasture and/or the animal. There is evidence to suggest that certain induced deficiencies could be corrected by an organic matter adjustment either through cultivation or the application of grass-killing chemicals.

Under low fertility conditions sward root systems tend to become extensive and exploratory and organic matter tends to accumulate. Under such circumstances a trial was laid down on hill country in which a molybdenum deficiency in clover was corrected following the application of paraquat (also referred to in section "Inter-actions of Chemicals, Fertilisers and Lime" (2) in this report).

The Periodic use of grass-killing chemicals would therefore appear to be one way of helping to maintain a good mineral balance in soils without resorting to cultivation. However, in soils which form a stable organic matter complex highly resistant to bacterial breakdown (such as the high allophane volcanic ash soils of New Zealand) imbalance may be difficult to avoid with the progressive organic matter build-up.

A recent 38-day trial (Wilson 1964) with dairy calves has revealed significant responses during the spring period to trace element supplements containing selenium and copper in areas other than those generally recognised as being deficient in these minerals. It is suggested that such deficiencies may not occur in recently renovated pastures due to the release of trace elements from organic matter breakdown.

Evidence from animal trials in this country (Andrews 1959) suggests that cultivation and/or cropping can effect the cobalt status of soils. Presumably the use of grass-killing chemicals would have a similar effect.

REFERENCES:

ANDREWS, E.D. (1959) Trace Elements in Soils & Pastures in relation to animal health. Proc. N.Z. Inst.Agric.Sci. P111-118.

BLACKMORE L.W. (1957) Chemicals as an Aid to Oversowing & Crop Establishment. Proc. 10th N.Z.Weed Control Conf. P18-23.

BLACKMORE L.W. (1958) Overdrilling of Pastures & Crops. N.Z.J.Agric.96:121-29.

BLACKMORE L.W. (1958) Some Practical Aspects of the Chemical Treatment of Pastures. Proc.11th N.Z.Weed Control Conf. P103-8.

BLACKMORE L.W. (1960) Chemical Pasture Establishment on Steep Hill Country N.Z. J.Agric. 100: 125-31.

BLACKMORE L.W. (1961) The Possibilities of Chemical Ploughing on Hill Country Unsuitable for Cultivation. Proc.14th N.Z.Weed Control Conf. P.53-59.

BLACKMORE L.W. (1962) Band Spraying - A New Overdrilling Technique. N.Z.J.Agric. 104: 13-19.

BLACKMORE L.W. (1962) Renovation of Pastures With the Aid of Chemicals. Proc. Ruakura Farmers' Conf. P97-107.

BLACKMORE L.W. (1964) Chemical Renovation of Pastures in Southern Hawkes Bay & Northern Wairarapa. Pt.1 & 2, N.Z.J.Agric.108: 122-135, 223-234.

BLACKMORE L.W. (1964) Chemical Pasture Renovation. Massey University Dairy Farmers' Conf.

BLACKMORE L.W. (1964) Chemical Establishment & Renovation of Pastures in N.Z. Proc.10th Internat. Grassl. Congress, Brazil.

JACKMAN R.H. (1955) Organic Phosphorus in N.Z. Soils Under Pasture. Soil Sci. 79: (207-211 and 293-299).

JACKMAN R.H. (1960) Organic Matter Stability and Nutrient Availability in Taupo Pumice. N.Z.J.Agric. Res. 3: 6-23.

LEONARD W.F. (1964) Grass Suppression in Clover Seed Crops. Proc. N.Z. Weed Control Conf. P.49-52.

WILSON G.F. (1964) Responses in Dairy Calves to Mineral Supplements. N.Z.J.Agric. Res. 7: 432-3.

THE USE OF BIPYRIDYLS AS AN AID TO PASTURE RENOVATION IN SOUTH AUSTRALIA

M.A. Ross and P.S. Cocks,
Department of Agriculture, South Australia.

Synopsis - Diquat and paraquat were shown to suppress annual weed seedlings sufficiently to allow the seedlings of sown pasture plants to establish.

Higher application rates and earlier spraying improved seedling establishment, but had less effect on the production of the sown species.

INTRODUCTION

The agricultural areas of South Australia have a typical Mediterranean environment with winter rainfall and summer drought. Many of the improved pastures consist of annual grasses and annual legumes. In some seasons these pastures suffer intense competition from annual weed species such as cape weed (Cryptostemma calendula L.), geranium species (Erodium botrys and E. moschatum, L. Herit), barley grasses (Hordeum hysterix Roth and H. Leporinum Link), silver grass (Vulpia species) and various Bromus species.

More stable pastures can be achieved and weed invasion can be prevented by the introduction of vigorous winter growing perennial grasses which are capable of surviving the dry summer conditions becauee of summer dormancy. The method of introducing these grasses using a "sod seeding" technique together with diquat and paraquat has been investigated.

DESICCATION WITH BIPYRIDYLS

In previous work, diquat has been shown to control the broadleaved weeds encountered, whilst paraquat at similar rates has controlled Bromus species and Hordeum leporinum. For the control of H. Hysterix and silver grass, higher rates were necessary. Neither herbicide permanently damaged subterranean clover or established perennial grasses. The rate of herbicides required increased with the age of the weed.

METHODS AND MATERIALS

Experiment 1: This experiment was located at Mt. Barker in the Adelaide Hills on a sandy loam under a 31 inch annual rainfall, where the main weed species were Cryptostemma calendula L., Erodium moschatum, Hordeum leporinum and Vulpia species.

The design was fully factorial in which plots were sprayed with 0, ½ and 1 oz. paraquat ion per acre at 14, 21 and 35 days after weed germination. Each treatment received 1 oz. diquat ion per acre at the same time as the paraquat. Each herbicide was applied in 30 gallons of water per acre with 1 pint of Agral L.N. added per 100 gallons. Four pasture grasses, Lolium perenne, Phalaris tuberosa, Phalaris coerulescens and Dactylis glomerata (variety Currie), were sod seeded separately at 15, 4, 4 and 6 lbs/acre respectively. A disc sod seeder sowed the seeds at a depth of ½" into the sprayed, but uncultivated pasture. Grasses were sown on the same day as the plots were sprayed in all combinations with the spraying. Each treatment was replicated four times.

Experiment 2: This experiment was located at Kybybolite in the South East of South Australia on a solodized solonetz soil under a 21 inch annual rainfall where the main weed species were Cryptostemma calendula L. and Lolium rigidum.

Again the design was fully factorial except that plots were sprayed on only one occasion, seventy days after weed germination, and sown 60, 73 and 84 days after germination with the same species and sowing rates of pasture grasses as in Experiment 1.

RESULTS

Experiment 1: Both early spraying and increased rates of paraquat enhanced establishment of sown grasses. This is illustrated in Figures A and B. Both effects were independent for all species except Phalaris coerulescens which produced a significant positive teraction. The time of sowing, which is more dependent on weather conditions than time of spraying, showed significant differences with only some species and these differences were very small compared with the effects of time and rate of spraying.

Experiment 2: In this experiment which was conducted later after weed germination, later sowing and increased rates of diquat both contributed to good establishment (Figure C). The magnitude of these differences was not reflected in herbage production taken during the following winter (compare Figures C and D). Re-infestation of plots by capeweed was rapid, unless a perennial grass was sown, and the more vigorous the early growth of the grass, the lower the proportion of invading capeweed (Figure E).

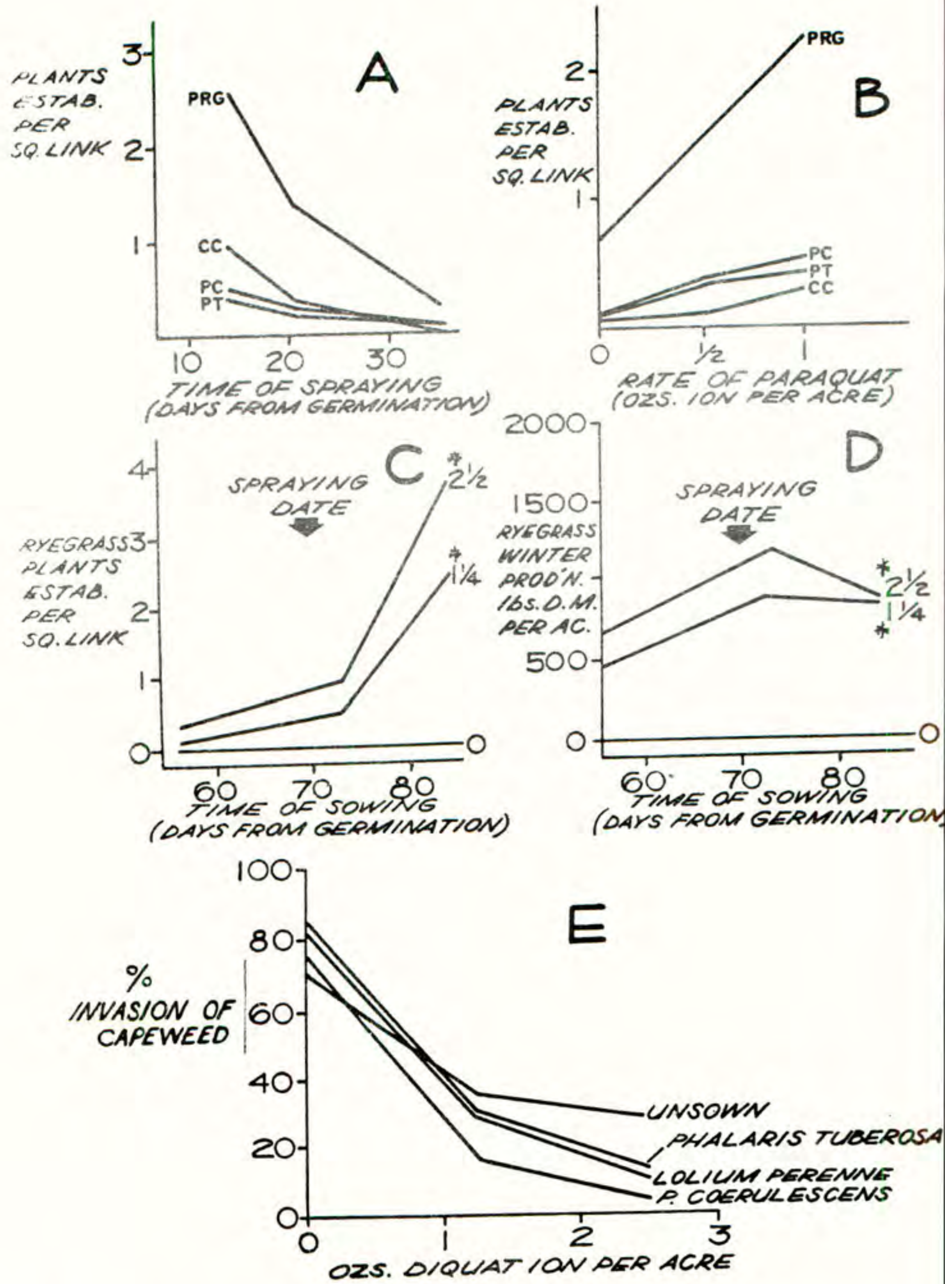
DISCUSSION

Trials have shown that perennial ryegrass can be successfully established by disc seeding into an uncultivated seedbed, with the aid of diquat and paraquat herbicide sprays. The establishment of *Phalaris tuberosa*, *P. coerulescens*, and Currie Cocksfoot was less successful. Higher application rates of herbicides may have improved the establishment of these species. A continuous establishment response was recorded up to 2½ ozs. diquat ion per acre, which was the highest rate used. Treatments as low as 1 oz. diquat ion plus ½ oz. paraquat ion per acre have produced a clean seedbed. Rates of herbicides above these produced no cleaner seedbed, but improved the establishment of the sown grasses.

Some factors not studied in the trials also influence perennial grass establishment. Adequate rainfall before and after sowing, for example, is necessary for good establishment, but all weather conditions influencing establishment are necessarily confounded with time of sowing relative to the stage of weed growth.

Control of regrowth and germination of weed species subsequent to spraying is also necessary for successful establishment. Unless this competition is removed by grazing, young seedlings of sown perennial grasses may be smothered.

The general acceptance of chemical seedbed preparation is very much dependent on economic factors. Where mechanical cultivation is not possible, as on steep country or shallow soils, or when weather is unfavourable, no alternative is available. However, where both methods are applicable, chemical seedbed preparation is in some cases proving the more economical method.



Figs C + D * indicates 1¼ and 2½ oz diquat ion per acre

Research Summary

THE USE OF PARAQUAT IN HILL LAND SURFACE SEEDING

J. F. YOUNG
Grassland Dept., School of Agriculture, Aberdeen

Summary The object of this work is to investigate the use of paraquat in the surface seeding, without any cultivations, of a limited range of predominantly grassy sites. The sites were representative of boggy, rocky or other difficult situations inaccessible to machinery, and consequently could not be scarified even lightly, as recorded by Jones (1962).

Preliminary results show that 1 lb. a.i. of paraquat per acre often had a similar effect to 2 lb. The susceptibility of different species is discussed, but Holcus lanatus presents a particularly serious problem. Early application of lime and slag has so far shown no advantage but grazing control is important. The surface seeding of rape was a complete failure. A tentative programme of operations is suggested for the future.

INTRODUCTION

Previous experience by Clouston (1943), Copeman and Roberts (1960) and Roberts (1960a) has indicated the possibility of achieving a valuable low-cost improvement by surface seeding in the absence of any cultivations, with the application of lime, phosphate, seeds and fertiliser alone. This type of improvement is very slow, but is possible on heather (Calluna vulgaris) dominant areas, in the absense of hill grasses, and provided there is adequate moisture for the seedlings. On the other hand when drought or a substantial proportion of natural grasses occurs, the slow establishment of a surface-seeded mixture almost inevitably results in failure. The established natural grasses will respond to the applied fertiliser and can compete excessively with the sown species.

Normally a waterlogged peat carrying a plant cover of grasses, rushes and sedges is considered unsuitable for surface seeding. On a few occasions when a grass and clover sward has been established these wetter areas show a marked drying out under the sown sward. It therefore seemed possible that paraquat offered several attractive features for use under these conditions, where both dalapon and amino-triazole had proved to be of only very limited value.

METHODS AND MATERIALS

In 1962 an initial examination of paraquat was made at eight centres. Three rates of paraquat as 'Gramoxone' (1 lb., 1½ lb. and 2 lb. a.i. per acre) were used with a wetter, and a comparison was made with two rates of amino-triazole (4 lb. and 8 lb. a.i. per acre). The results with all rates of paraquat were spectacular, independent of heavy rain immediately after spraying, and showed a good kill. The plots sprayed with paraquat also remained bare and open for over a year on the better sites.

In 1963 experiments were laid down to investigate the practical aspects of using paraquat to weaken or inhibit the response of moorland vegetation to lime and fertiliser applications. Four sites which were very difficult subjects for improvement, although typical of only a small fraction of the area as a whole, were chosen on open hill grazings lying between 500 and 1200 feet in Aberdeenshire, Banffshire and Inverness-shire. The herbage was in all cases predominantly grassy and ranged from Agrostis tenuis, Holcus lanatus, Nardus stricta, Anthoxanthum odoratum and Molinia caerulea dominant on the drier parts to Carex panicea, C. binerva, C. echinata and Juncus communis on the wetter parts.

The areas were fenced and 50-60 cwt./acre of ground limestone and 9 cwt./acre of 18% basic slag were applied to all plots in the summer of 1963. The first spraying was carried out in July 1963, when there was sufficient green growth for the spray to be effective. Four rates of application of 'Gramoxone W' were employed, giving 2, 1, ½ and ¼ lb. a.i. of paraquat in 20 gallons of water per acre, and the following were the times of spraying and subsequent treatments.

	Spraying	Burning	Seeding and Fertilising
1.	July 1963	-	Immediately
2.	Do.	-	Late April 1964
3.	Do.	Spring 1964	Do.
4.	Early Oct. 1963	-	Do.
5.	Do.	Spring 1964	Do.
6.	July 1964	-	Immediately
7.	Do.	-	Spring 1965
8.	Do.	Winter '64-65	Do.

These treatments were designed to show the time of year during the short growing season of moorland herbage when spraying was most effective. It was also hoped to ascertain whether the advantage of the mulching effect of immediate seeding suggested by Jones (1962) was outweighed by seedling damage resulting from paraquat remaining on the dead foliage. The value of burning to remove surface trash, and finally the effect of early application of lime and slag on the success of subsequent treatments may also be demonstrated.

At a fifth site it was impossible to burn the short herbage which was grazed by deer each winter. The burning treatments were therefore replaced by the surface seeding of 3½ lb./acre of rape at the time of sowing the grass and clover seeds.

Similar experiments have been carried out at several other sites in Aberdeenshire and Kincardineshire. Two of the most interesting were, firstly, on old felled pine-wood, and secondly on stabilised sand-dunes where wind erosion made it desirable to retain the surface cover. On these sites lower rates of paraquat were employed, (viz. 1, ½, ¼ and ⅛ lb. a.i. per acre) and spraying as early as May was possible.

RESULTS AND DISCUSSION

The conclusions can only be tentative, as the experiments are still in progress. This caution is further emphasised by the fact that in the eastern part of Scotland surface seeding, without any mechanical cultivations, is always a slow method of improvement.

Rate of Application

A rate of 1 lb. a.i. of paraquat per acre has initially appeared to produce a similar effect to that of 2 lb. per acre under most conditions. The effect of the lower rates of ½ and ¼ lb. a.i. per acre is noticeably less. Where the herbage is very dense, the highest rate of 2 lb. per acre shows to advantage, and it seems probable that either this higher rate of application or a greater volume of spray may be required in very dense growth. Where the herbage is shorter and less surface trash is present, as on the felled woodland and sand-dune sites, the lower rates of 1 lb. and even ½ lb. a.i. per acre are more comparable with the 2 lb. rate.

Effect on Species

The application of 2 lb. or 1 lb. a.i. of paraquat per acre appeared to suppress Agrostis tenuis, Anthoxanthum odoratum, Molinia caerulea, Juncus squarrosus and, to a variable extent, Nardus stricta. Holcus lanatus, Festuca rubra and Poa pratensis were only slightly affected, and showed a rapid response to the application of fertilisers. In respect of Holcus lanatus results apparently differ from findings elsewhere, in which established plants have proved susceptible, and rapid recolonisation, if any, appears to take place principally from seedlings. Carex spp., Juncus spp. other than J. squarrosus, Trifolium repens and a wide range of dicotyledonous species appeared little affected, but these have so far proved to present no serious difficulty.

Effect of Lime and Slag

The early application of lime and basic slag has so far shown no outstanding advantage. All plots were limed and slagged at the same time, but were sprayed at three subsequent times. Some sites appear better when sprayed soon after application, whereas later spraying appears better on others. Any differences may only be the effect of the time of year when the spray itself was most efficient, and the full effects of the time of application of lime and slag will not be assessable until next year when a direct comparison between 1963 and 1964 spraying times will be possible.

Control of Grazing

For successful surface seeding, grazing control is essential. Growth of the original herbage which has survived the spray is enhanced by the application of fertiliser, but tends to be more palatable to stock. Heavy grazing in mid-summer, preferably by cattle, is therefore an essential complement to the use of paraquat. Grazing also makes the sown grasses tiller and encourages the clover. These areas must also be protected in the first years from winter grazing and the excessive early sheep grazing to which this type of improved land is so frequently subjected.

By delaying the application of nitrogen Roberts (1960b) obtained better results from surface seeding, and this may help to reduce the critical importance of careful grazing control.

Rape

When rape was surface seeded it was a complete failure. The seeds germinated but the cotyledons showed chlorosis starting round the margins, which then spread until the plants died. The roots appeared undamaged. It seems untenable that this could have been the residual effect of paraquat reported by Hammerton and Johnson (1962), who sowed three days after spraying, for in this case the spraying had been carried out either seven or nine months before sowing. It seems much more likely that it was an effect of drought or trace element deficiency on the thin sandy soil of this site, which the sown grasses and clovers were able to survive.

Present Recommendations

A tentative programme suggested for this type of grassland improvement based on present very limited experience is:-

Winter	- Burn if possible during winter.
Spring	- Apply lime and basic slag.
Summer or Early autumn	- Fence off area.
Early autumn	- Spray with 1-1½ lb. of paraquat per acre in 20-40 gallons water.
Early winter	- Burn dead herbage.
Spring	- Sow seeds with phosphate and potash.
Early summer	- Apply nitrogen.
Late summer	- Cut ditches to improve drainage during the subsequent winter.

References

1. CLOUSTON, D. (1943) The Improvement of Heath and Moorland Grazings. Scot. J. Agric. 24, 104-112.
2. COPEMAN, G.J.F. & ROBERTS, H.W. (1960) The Development of Surface Seeding. J. Brit. Grassl. Soc. 15, 163-168.
3. HAMMERTON, J.L. & JOHNSON, R.J. (1962) Establishment of Rape in Grass Swards by Use of Sod-Seeder and Herbicides. J. Brit. Grassl. Soc. 17, 229-230.
4. JONES, LEWIS (1962) Herbicides to Aid Pasture Renovation. J. Brit. Grassl. Soc. 17, 85-86.
5. ROBERTS, H.W. (1960a) Chemical Renovation of Hill Land in the North of Scotland. Trans. Highl. agric. Soc. Scot. 5, 29-37.
6. ROBERTS, H.W. (1960b) The Delayed Application of Nitrogen for the Establishment of Surface-Seeded Swards. J. Brit. Grassl. Soc. 15, 287-290.

HERBICIDES AS AIDS IN HILL-PASTURE IMPROVEMENT

R. G. Heddle and Colin D. Young
The Edinburgh School of Agriculture

Summary Paraquat at 0, 2, 4, 8, 12 and 16 oz/ac ion was applied to a previously sod-seeded Nardus/sheep's fescue hill pasture in March, July, September and December.

July and September proved to be the most effective times of application to control Nardus: March was practically ineffective.

Sheep's fescue recovered more rapidly from July spraying than from any other date.

In terms of control of Nardus, coupled with increase in the fescue content of the sward, the best result was obtained by applying 16 oz/ac in July.

White clover and Poa spp. were relatively unaffected by treatment except that rough-stalked meadow-grass increased after the September and December applications at the higher rates.

Pretreatment of a similar sward with paraquat, dalapon, dalapon + trilopon, and amino-triazole at various rates led to improved establishment of white clover and grasses subsequently oversown on the surface.

INTRODUCTION

One limiting factor in improving certain types of hill pasture is the complete absence of white clover from the sward. In such swards, even where soil conditions are ameliorated by applying lime and fertilisers, the response, in terms of change in botanical composition, may be poor.

In recent years attempts have been made, on the hill land of the Bush Estate of The Edinburgh School of Agriculture, to establish white clover in such swards by sowing seed. Two methods have been tried: (1) sod seeding, in which furrows some 4 in. wide are taken out at approximately 3 ft intervals by means of a specially designed machine, the seed being simultaneously sown in the furrows along with lime and phosphatic fertiliser: (2) oversowing seed on the surface of the existing sward, either with or without steps being taken, e.g. by burning or using a forage harvester, to remove excessive top growth.

Using the sod-seeding technique it has not been difficult, in seasons of adequate rainfall, to establish white clover, as well as certain grasses, rough- and smooth-stalked meadow-grasses, S50 timothy, in the furrows. It was hoped that by subsequently top-dressing between the furrows the creeping species would be induced to spread and colonise the entire area. In favourable circumstances this has occurred but in other cases spread has been very limited. This is attributed to several factors, one being the exposure of the plants in the furrows to intensive grazing by the sheep, another the competition which the introduced species suffer from the existing vegetation.

Oversowing of white clover seed on the uncultivated surface of the sward has met with varying success. At best good establishment has been secured, but in some cases complete failure has resulted. Even where establishment is successful, however, the introduced plants have to compete with the natural vegetation consisting of plants often of an unpalatable character, e.g. Nardus stricta, which are neglected by sheep and may get very coarse, or of species such as sheep's fescue which form dense swards not easily invaded.

The experiments described in this paper were designed to investigate the effects of using herbicides to destroy or check the natural vegetation, with a view to reducing its competitive effect on introduced species, especially white clover. Two series of experiments are described here.

Experiment 1

This experiment was designed to study the effects of varying the date and rate of application of paraquat on the vegetation of an area of Nardus/sheep's fescue, sod-seeded in 1959 and with white clover well established in the furrows. It was situated on Castlelaw Hill, Bush Estate, at 1,100 ft elevation.

METHOD AND MATERIALS

The layout was a 4 x 4 Latin square with split plots, the main plots being assigned to application dates, the sub-plots (each 2 yd x 10 yd) to rates. Dates of spraying were: 21 March, 17 July, 21 September, 1 December, 1963. Rates of application were: 0, 2, 4, 8, 12 and 16 oz ion./ac.* The March application was made with an Oxford Precision sprayer with Allman No. 0 jets, at 20 lb pressure/in^2 and 30 gal/ac. Owing to persistent high winds the July application had to be made with a watering can and dribble-bar at 90 gal/ac. The September and December applications were made with a hand-operated Vermorel sprayer, fitted with the Oxford boom and Allman No. 0 jets, at a pressure of about 5 lb/in^2.

Botanical analyses were carried out by means of a point quadrat, recording only first "strikes". Plots were analysed at intervals but only the latest record, that of August, 1964, is fully considered here.

RESULTS

Tables 1-6 summarise the results in respect of the major species, viz. Nardus and sheep's fescue, introduced species, viz. white clover and the two meadow grasses, and the area of bare ground and dead vegetation.

* As Gramoxone

Table 1

Bare ground and dead vegetation: per cent cover, August, 1964

Application rate (oz/ac):	0	2	4	8	12	16	Mean
March	1.0	0.3	1.5	1.3	2.0	3.7	1.6
July	1.0	1.0	1.3	6.0	7.5	9.3	4.3
September	0.7	7.0	12.7	30.3	43.5	51.3	24.3
December	0.3	9.7	12.3	17.5	27.5	41.0	18.0
Mean	0.7	4.5	6.9	13.8	20.1	26.3	

SE mean of dates $\pm$ 2.0 ***

SE mean of rates $\pm$ 1.3 ***

Date x rate interaction ***

The amount of bare ground and dead herbage increased with increasing dosage rate: there was also a large difference between the means for different spraying dates, March and July being low in contrast to September which was very high and December which was slightly lower. An even more striking feature, however, was the marked interaction between rate and date of application. When application was made in March the amount of scorching immediately following was proportional to application rate. This condition persisted in diminishing degree throughout the following year but by August, 1964, it had virtually disappeared. The July application showed a similar trend but the heavier rates still showed an effect in August, 1964. The September-sprayed plots were much slower in recovering and a year after treatment up to 50 per cent of the ground was still bare following the 16 oz application. The December application was similar but not quite so severe in its effects.

Table 2

Nardus stricta: per cent cover, August, 1964

Application rate (oz/ac):	0	2	4	8	12	16	Mean
March	33.3	36.0	48.0	39.7	36.0	40.5	38.9
July	39.0	27.7	22.5	12.7	9.5	4.0	19.3
September	37.5	26.7	12.3	12.7	4.0	5.0	16.4
December	34.5	40.3	33.0	25.3	20.7	17.3	29.3
Mean	37.3	32.7	28.9	22.6	17.6	16.7	

SE mean of dates $\pm$ 5.1 NS

SE mean of rates $\pm$ 1.0 ***

Date x rate interaction ***

On average there was a steady decline in the amount of Nardus in the sward up to an application rate of 12 oz a.i./ac: date of application also showed an effect, March being the least effective date, while July and September both showed a considerable reduction and December was intermediate. There was again a strong rate x date interaction. Spraying in March had no significant effect on Nardus but the June and September applications resulted in a pronounced reduction, the 16 oz rate killing about 90 per cent of the Nardus originally present in the sward. The December application was less effective, the 16 oz application giving about 50 per cent kill.

Table 3

Sheep's fescue: per cent cover, August, 1964

Application rate (oz/ac):	0	2	4	8	12	16	Mean
March	30.0	32.0	24.7	27.7	31.3	23.7	28.3
July	31.3	46.5	54.0	56.7	59.5	66.0	52.3
September	34.7	39.5	43.7	32.0	24.3	15.5	31.6
December	30.0	19.5	14.3	11.7	10.0	6.3	15.3
Mean	31.5	34.4	34.2	32.1	31.3	27.9	

SE mean of dates ± 2.6 ***

SE mean of rates ± 1.5 *

Date x rate interaction ***

Date of application had a marked effect on sheep's fescue. The July application resulted in an ultimate increase which was already evident by May, 1964, while the December application resulted in a reduction. There was again a very marked date x rate interaction. The effect of the March treatment was a temporary reduction at the highest rates of application which by the time of the August, 1964 record had largely disappeared. The July application, on the other hand, resulted in a very decided rise in the amount of fescue in the sward, increasing with increase in application rate. This, in turn, contrasts with the effect of the September and December treatments, the former permitting a slight increase of fescue at the 4 oz rate but causing a reduction at the 12 and 16 oz rates, while the latter resulted in a reduction at all rates.

Table 4

White clover: per cent cover, August, 1964

Application rate (oz/ac):	0	2	4	8	12	16	Mean
March	11.5	8.7	8.7	10.7	9.0	8.7	9.6
July	6.7	9.3	3.5	8.7	5.3	7.5	6.8
September	6.0	4.7	6.0	1.3	3.0	3.0	4.0
December	9.7	8.7	8.5	10.3	11.3	6.7	9.2
Mean	8.5	7.9	6.7	7.8	7.1	6.5	

SE mean of dates ± 1.3 NS

SE mean of rates ± 1.1 NS

Date x rate interaction NS

In respect of neither date nor rate of application were the differences in white clover contribution to the swards significant: nor was there any significant date x rate interaction.

Table 5

Smooth-stalked meadow-grass: per cent cover, August, 1964

Application rate (oz/ac):	0	2	4	8	12	16	Mean
March	6.5	5.3	4.0	1.5	2.7	4.3	4.0
July	7.3	4.3	4.0	6.7	7.5	5.0	5.8
September	7.7	8.0	4.0	3.5	3.5	3.0	5.0
December	6.5	4.5	9.7	8.7	3.5	4.3	6.2
Mean	7.0	5.5	5.4	5.1	4.3	4.1	

SE mean of dates ± 0.7 NS

SE mean of rates ± 0.8 NS

Date x rate interaction NS

There appears to be here a tendency to reduction of this species with increasing rate of application but the result is not significant at the 5 per cent level of probability.

Table 6

Rough-stalked meadow-grass: per cent cover, August, 1964

Application rate (oz/ac):	0	2	4	8	12	16	Mean
March	3.0	3.3	2.0	3.0	3.5	3.5	3.0
July	4.3	3.0	5.3	1.3	2.5	1.0	2.9
September	1.3	2.0	4.0	8.5	10.3	9.0	5.8
December	2.0	4.3	6.0	8.3	5.5	8.3	5.7
Mean	2.6	3.1	4.3	5.3	5.4	5.4	

SE mean of dates $\pm$ 1.7 NS

SE mean of rates $\pm$ 0.9 NS

Date x rate interaction *

The only statistically significant feature in this record is the greater amount of rough-stalked meadow-grass in the swards sprayed with 8 oz or more in September and November. March and June do not show this effect.

DISCUSSION

The outstanding feature in this experiment is the totally different results obtained from the different spraying dates, particularly in relation to the dominant species, Nardus and sheep's fescue.

In the March-sprayed plots Nardus was not affected to any appreciable extent. The fescue showed a pronounced initial reduction, followed by a gradual recovery as it reoccupied most of the bared ground. By August, 1964, there was very little difference between the control and the sprayed plots.

The July-sprayed plots, in contrast, showed a marked reduction in Nardus, the degree of reduction being broadly in proportion to the rate of application, with a maximum effective control of about 90 per cent at 16 oz/ac. Fescue, on the other hand, showed an increase from all rates of application, again broadly in proportion to rate of application: at the 16 oz rate the amount of fescue in the sward was doubled by August, 1964.

In the September-sprayed plots, as in July, Nardus suffered a reduction comparable in severity to that from the July treatment. The fescue, however, behaved differently: there was a slight increase as a result of the 2 and 4 oz applications but above the 8 oz level a reduction was produced.

In the December-sprayed plots Nardus was reduced, but not to the same extent as from July or September spraying, the maximum reduction being about 50 per cent as compared with the control. In the December-sprayed series, however, fescue suffered very severely. It was reduced even by the 2 oz application and progressively more the greater the application rate. 16 oz reduced it to about 20 per cent of its original cover.

These variations in results indicate that the susceptibility of a particular species may vary widely from time to time. Nardus was very resistant in March, at which time it was more or less dormant and such young growth as was present would be considerably protected by the accumulation of ungrazed herbage of the previous year's growth. The more palatable fescue, which was grazed short and more fully exposed to the spray, suffered more damage. With time, however, it slowly recovered to re-establish itself on the ground bared as a result of spraying. Nardus has a very limited capacity for vegetative spread and could not rapidly occupy the bare ground.

In July Nardus which was rather beyond its maximum growth stage, was evidently very susceptible to paraquat. The fescue at this season was more resistant and recovered comparatively quickly from the effect of the spray. The removal of the competition of Nardus gave the fescue full opportunity to colonise the bare ground and by August, 1964, it had largely, though not entirely, occupied the available space.

In September Nardus appeared to be as susceptible as in July but fescue no longer exhibited the high degree of tolerance which it showed in July. Thus, while the amount of bare ground available for colonisation was large, the fescue had been checked to such an extent that it was unable to occupy the available space. The slight increase in fescue noted at the 4 oz rate of application may be attributed to the lesser degree of injury suffered at this rate, coupled with sufficient reduction in Nardus to leave room for the fescue to spread. At rates above 8 oz, however, the direct injury to the fescue was sufficient to handicap it to such a degree that it was unable to occupy the bare ground available some twelve months after spraying. It is clear from the large proportion of bare ground that the vegetation on these plots is still far from reaching stability.

In December Nardus, while still showing some susceptibility to paraquat, was more resistant than in July or September: applications of less than 8 oz had no effect on it. Fescue, on the other hand, showed extreme susceptibility at this season, even 2 oz having a marked effect. As in the September-sprayed plots, the vegetation has not yet reached stability and fescue may yet recover, but its spread will clearly be limited by the surviving Nardus.

From the point of view of improving the sward by reducing the very unpalatable Nardus and encouraging the more useful sheep's fescue, the most successful result has been obtained from the July spraying. At this season control of Nardus improved consistently with increase in rate of application of paraquat up to 16 oz/ac.

As regards the other species considered, white clover and the meadow grasses, results up to the present are not particularly encouraging. White clover and smooth-stalked meadow-grass show no significant increase on the sprayed plots: in fact the latter appears o show a slight, if insignificant, reduction. As regards rough-stalked meadow-grass, it is evident that the higher rates of application, (8 oz and upwards), in September and December, but not in March or July, have been followed by an increase in this species. This is no doubt due in part to the failure of the fescue to recover at these levels of application but it suggests a relatively high degree of tolerance of paraquat by rough-stalked meadow-grass at this time of year.

Experiment 2

This experiment involved a comparison of the effect of 3 herbicides, each at 3 application rates, upon the subsequent establishment of white clover and grasses.

METHOD AND MATERIALS

The site was on Castlelaw Hill at an elevation of 1,300 feet on a vegetation dominated by Nardus and sheep's fescue. The soil was peaty with a surface mat; pH 5.8; drainage somewhat impeded.

The area was "topped" with a flail-type forage harvester on 15th May, 1963, and the debris removed. 3 tons/ac $CaCO_3$ were applied 5th June and 24 cwt/ac 12 per cent slag on 24th June.

Layout: randomised block of 4 replicates; plots 10 yd x 2 yd.

Treatments, applied 10th June with Oxford Precision sprayer with Allman No. 0 jets at 20 lb/in² and 30 gal/ac.

Dalapon: 3, 6, 9 lb a.i./ac.

Dalapon + trilopon*: 3.6, 7.2, 10.8 lb a.i./ac.

Amino-triazole: 2, 4, 6 lb a.i./ac.

Control: unsprayed.

On 17th July half of each plot was sown with a 50:50 mixture of New Zealand (mother seed) white clover and wild white clover at 4 lb/ac: the other half received in addition 4 lb S50 timothy and 2 lb rough-stalked meadow-grass/ac. No cultivation was carried out.

Clover counts were made in September, 1963, and June, 1964: grass counts in June, 1964, only. 10 counts were made per half plot using a 6 x 6 in. quadrat.

RESULTS

Detailed botanical analyses were not made but the following notes summarise observations on the plots.

Dalapon and dalapon + trilopon were similar in their effects: they

* As Dalacide: 78 per cent a.e. dalapon, 8 per cent a.e. trilopon

Table 7

Number of seedlings/1 yd^2 on plots treated with herbicides

Species	Date of count	Dalapon 3	Dalapon 6	Dalapon 9	Dalapon + trilopon 3.6	Dalapon + trilopon 7.2	Dalapon + trilopon 10.8	Amino-triazole 2	Amino-triazole 4	Amino-triazole 6	Control	SEM
White clover	Sept. 1963	65.5	86.0	75.5	104.5	79.0	97.0	81.5	43.0	82.0	50.5	± 10.6**
	June 1964	43.0	42.0	43.0	18.5	37.0	52.3	37.0	20.5	30.0	25.0	± 7.5*
Timothy	June 1964	19.0	45.0	50.0	25.0	48.0	45.0	18.0	31.0	16.0	7.0	± 7.7**
R.S.M.G.	June 1964	47.0	79.0	63.0	42.0	49.0	91.0	59.0	71.0	75.0	14.0	± 17.5NS

Material and application rate (lb/ac)

acted more slowly than paraquat (see experiment 3, infra) and the "kill" of vegetation was never so complete. By spring it was evident that the kill of Nardus by these two herbicides was greater than that achieved with paraquat. Amino-triazole was less effective. At the 2 lb rate it differed little from the control; at the higher rates there was more bare ground.

DISCUSSION

Initial seedling establishment of white clover showed an improvement on most of the plots treated with herbicides. By the following June there had been heavy mortality among the seedlings, amounting to more than half of those counted in September. There was still a substantial improvement in establishment on all the dalapon plots, the dalapon + trilopon being more variable and the amino-triazole slightly lower on the average. There is a parallel between establishment figures and the degree of damage to the original vegetation caused by the sprays.

Timothy also showed an improvement in establishment following spraying. In general the lowest rate of application led to some improvement, doubling the rate to a further imrovement, but the highest rates of dalapon and dalapon + trilopon gave no further increase and in the case of amino-triazole there is some indication of a fall at the highest rate, possibly due to a residual toxic effect.

The results for rough-stalked meadow-grass were too variable to be conclusive but do suggest an improvement over the control plots for all treatments.

Experiment 3

This experiment consisted of a comparison of the effects of 4 rates of paraquat application on subsequent seedling establishment.

METHOD AND MATERIALS

The site adjoined that of experiment 2 and, apart from the herbicidal applications, the treatments in both experiments 2 and 3 were identical. The layout was a randomised block with 4 replications. Paraquat was applied at 0, 0.5, 1.0, 1.5 and 2.0 lb/ac using the Oxford Precision sprayer with Allman No. 0 jets at 20 lb/in² pressure and 30 gal/ac.

Counts of seedlings were made at the same time and by the same methods as in experiment 2.

RESULTS

The paraquat took effect more rapidly than did the chemicals used in experiment 2: by early August the 1.5 and 2.0 lb plots appeared dead apart from the survival of *Carex binervis*, while the 0.5 and 1.0 lb plots also showed a high degree of kill.

Table 8

Numbers of seedlings/1 yd^2 on plots treated with paraquat

Species	Date of count	Rate (lb/ac) 0	0.5	1.0	1.5	2.0	SEM
White Clover	Sept. 1963	23.0	81.5	63.0	92.5	91.0	±13.3**
	June 1964	17.0	24.0	32.0	49.5	54.0	± 6.5**
Timothy	June 1964	12.0	28.0	36.0	48.0	29.0	± 8.6NS
R.S.M.G.	June 1964	10.0	34.0	30.0	55.0	54.0	±13.9NS

DISCUSSION

The September counts of white clover showed an improvement in establishment as a result of all treatments, but no significant difference between rates. Winter casualties were again heavy, amounting to about half the plants recorded in September. The June counts showed to the advantage of the heavier applications of paraquat.

The two grass species gave results which, while notstatistically significant, show an improvement in establishment from all treatments and a tendency, particularly in rough-stalked meadow-grass, towards better establishment following higher application rates.

THE TECHNICAL AND PRACTICAL SIGNIFICANCE OF CHEMICAL CULTIVATION IN WEST OF SCOTLAND HILL LAND IMPROVEMENT

I. V. Hunt

West of Scotland Agric. College,
Auchincruive, Ayr.

Summary

Improvements in hill herbage following the use of dalapon, paraquat and diquat are described used in combination with limestone and basic slag, with sown Trifolium repens or seed mixtures as well as used alone. These are compared with the results obtainable by harrowing and the 'Muirfad technique' and without pretreatment with herbicides. Attention is drawn to the need for investigations of systems of limited improvement adaptable to the vast acreages of inherent low output.

INTRODUCTION

Several experiments have been undertaken in the West of Scotland on the improvement of hill land by surface treatment. Tremendous improvements are possible using present day techniques of fencing, liming, slagging etc. with and without the accompaniment of cultivations or pretreatment with herbicides. The one factor which restricts the application of these techniques is cost. The subsidies hitherto available have never been sufficient to allow a big enough scale of improvement per farm.

Probably the biggest impetus to large scale improvement was the special subsidy available in the 'Crofting Counties' of Scotland by which 70% of the net cost of reclamation after all national subsidies had been received could be obtained. Thousands of acres were improved prior to the restriction of the full grant to genuine crofters. The aim of all these experiments has been limited improvement by the use of herbicides as an alternative to cultivation and not as an additional treatment.

RESULTS

Experiment E.94 (Table 1)

A variety of vegetational types of hill land at about 1000 ft. were sown with 2 lb/ac Trifolium repens each month from September 1956 to August 1957 following treatment with a) 2 ton/ac ground limestone plus 1 ton/ac basic slag or b) 10 cwt/ac basic slag or c) no manuring. During 1957 and 1958 counts of established Trifolium repens were made.

TABLE 1. CLOVER ESTABLISHMENT WITHOUT CULTIVATION

(mean counts per sq. yard July 1958)

		Site A		Site B	
Dominant herbage		Nardus stricta		Eriophorum vaginatum	
Loss on ignition		47.3%		77.0%	
pH		4.12		3.37	
Manuring levels	Limestone (1)	2 tons	None	2 tons	None
	Basic Slag	1 ton	10 cwt.	1 ton	10 cwt.
(2) Date of seed sowing	January 1957	6.8	0.3	9.0	0.8
	February 1957	4.5	0.3	12.6	0.1
	March 1957	14.3	1.5	24.0	0.1
	April 1957	12.0	0	18.8	0
	May 1957	5.3	0	6.0	0.5
	June 1957	0.8	0	3.8	0.2
	July 1957	1.5	0	11.3	0
	August 1957	0	0.3	10.5	0
	September 1956	3.0	0.1	6.8	0
	October 1956	5.3	0	7.5	0.5
	November 1956	3.8	0	4.5	0
	December 1956	1.5	1.3	10.5	0.7

(1) Limestone/Basic slag applied in August 1956
(2) S.100 White Clover sown by hand without any preparation or cultivation after sowing.

By July 1958, well established plants of Trifolium repens were to be found on some plots from all sowing dates with more from March/April sowings than from other months. By 1962, the areas given limestone were uniformly good with a large proportion of Agrostis, Holcus lanatus and Trifolium repens, whilst those areas given only 10 cwt. basic slag were still largely Nardus stricta. Both areas showed signs of more grazing than the untreated herbage, whilst the unfertilised areas sown with Trifolium repens were indistinguishable from untreated hill.

Experiment E.155 (Table 2)

An area of blanket peat overlying heavy clay with a herbage of Molinia caerulea, Agrostis, Juncus squarrosus, Carex spp, Potentilla erecta and Galium saxatile was sprayed with either Diquat, Paraquat or Dalapon at three rates. No seeds were sown, no fertilisers were applied and no cultivations took place except that sheep were allowed free access. Grazing was heavy on all the sprayed plots. Twelve months after spraying, there was a reduction in Molinia, and an increase in the better grasses, Festuca rubra and Poa sub-caerulea and an increase in Juncus and Carex. These trends were most noticeable for Dalapon and less so for Paraquat.

By 1962, the Paraquat and Dalapon treated areas were more closely grazed than the unsprayed areas or those given Diquat.

TABLE 2. EFFECTS OF HERBICIDES ON COMPOSITION OF NATURAL HERBAGE

		Better Grasses	Poorer Grasses	Rushes Sedges	Dicotyledous
Composition 1961					
Treatment 1960					
Spray lb/ac a.e.					
None	-	35	34	24	7
Diquat	1	56	26	14	4
	2	51	18	18	13
	4	42	23	27	8
Paraquat	1	41	20	30	9
	2	39	14	39	8
	4	34	15	36	15
Dalapon	2	38	11	25	26
	4	48	0	25	27
	8	56	0	18	26
Composition 1962					
Treatment 1960					
Spray lb/ac a.e.					
None	-	45	36	7	13
Diquat	1	54	40	2	4
	2	46	42	5	7
	4	52	33	2	13
Paraquat	1	31	50	7	12
	2	46	14	22	18
	4	40	10	32	10
Dalapon	2	66	4	15	15
	4	63	0	22	15
	8	47	10	30	13

Experiment E.28 (Table 3)

This experiment consisted of a series of botanical analyses and yield determinations from an area covered with *Calluna vulgaris*, *Myrica* gale, Molinia and Carex given the 'Muirfad treatment', viz. heavy dressings of ground limestone (3 ton/ac) and basic slag (2 ton/ac) and seed cleanings but with neither cultivations nor nitrogenous fertiliser. The area, although carrying a hill type vegetation lay at sea level and

TABLE 3. IMPROVEMENT BY 'MUIRFAD TECHNIQUE'

(% botanical composition 1952)

	Group 1 Erica spp. Scirpus caespitosus Myrica gale Molinia caerulea Luzula campestris Potentilla tormentilla Moss	2 Carex spp.	3 Holcus lanatus Poa pratensis Agrostis vulgaris Festuca rubra Festuca ovina Anthoxanthum odoratum Cynosurus cristatus	4 Lolium perenne Dactylis glomerata Phleum pratense	5 Trifolium repens
Year of Treat-ment					
1951	29.2	1.7	43.3	6.9	18.7
1950	4.1	4.3	44.6	13.9	32.8
1949	1.6	3.3	55.2	11.5	27.9
1948	1.0	7.7	38.0	13.0	45.0
1947	0	0	56.0	14.0	29.0
1946	0	16.0	49.0	8.0	27.0
None	93.7	2.5	4.5	0	0

once the natural herbage had been replaced by sown grasses, productivity increased. Now, 18 years after treatments began, the swards consist of Agrostis, Holcus lanatus, Lolium perenne, Cynosurus cristatus and Trifolium repens and although poor by comparison with leys on nearby mineral soil, they present a considerable improvement on the original state. During the last 4/5 years Juncus effusus has become established along and within the old open ditches.

Experiment E.99 (Table 4)

The contribution which lime and lime plus herbicide (as Dalapon) can make is illustrated in data shown in Table 4. This comes from an Experiment including seed coating with limestone and the application of sodium molybdate. The means show the marked effect of limestone and the beneficial effect of Dalapon in removing competing natural herbage.

TABLE 4. THE EFFECT OF LIME AND DALAPON ON WHITE CLOVER ESTABLISHMENT

		Limed	No Lime
Nos. of white clover Seedlings/sq. yard 23/9/57	After Dalapon	620	6
	No Dalapon	10	4
Areas of white clover in sq. inches per sq. yard 16/9/58	After Dalapon	54.6	0.1
	No Dalapon	6.0	2.6

Treatments Limed at 2 tons per acre 2/7/57
Dalapon at 10 lb/acre 10/6/57

Experiment E.186 (Table 5)

A steep hill slope dominated by *Molinia caerulea*, *Festuca rubra* and *Nardus stricta* has shown progressive improvement since treatment. The areas were given 3 ton/ac ground limestone and 2 ton/ac basic slag and sown with a seed mixture of *Lolium perenne*, *Dactylis glomerata* and *Trifolium repens* after harrowing or spraying with Dalapon. Five years after treatment the effects were still marked. The harrowed area is still distinct from the sprayed area having a characteristic roughness due to surviving natural herbage. The sprayed area soon became over-grazed and has not recovered from this state. Clovers remain small, grasses are whispy whilst there are bare or moss-covered patches.

TABLE 5. EFFECT OF HARROWING OR HERBICIDE ON ESTABLISHMENT OF GRASS SEEDS (% botanical composition)

	Date of Analyses	16/8/60		24/5/62	
	Treatment	Harrowed	Dalapon	Harrowed	Dalapon
Component	Perennial ryegrass	4	17	25	44
	Cocksfoot	2	4	23	22
	White clover	6	9	12	20
	Natural grasses	56	14	27	11
	Dicotyledous	4	13	2	-
	Dead matter	28	43	-	-
	Bare ground	-	-	11	3

All areas given 3 tons ground limestone and 2 tons basic slag and sown with S.24 perennial ryegrass 16 lb; S.23 perennial ryegrass 8 lb; S.143 cocksfoot 8 lb; New Zealand white clover 2 lb. per acre.

DISCUSSION

Although there are vast acreages of potentially improvable hill land, the cost of large scale, rapid improvement is beyond the capacity of most farm units. Various figures for net profit are quoted, but much of the land included in the term 'vast' realises an annual surplus of less than 10/- per ewe. This includes the profit from true hill plus associated better inbye land. Since the average ewe population ranges from 1 per acre to 1 per 10 acres it will be seen that improvement may have to be financed out of much less than 3/- per acre. The 'vast acreages' are fit subjects for limited low cost improvement whilst smaller and possibly commercially insignificant acreages can be given the full technical treatment.

In the former, one is not concerned with the possibility of replacing natural herbage by a *Lolium perenne/Trifolium repens* sward nor with the fact that *Festuca rubra* is resistant to herbicides.

Probably the simplest approach would be through the experiment referred to in Table 2 in which herbage can be modified by removing undesirable ungrazed herbage temporarily or permanently and replaced by the best of natural constituents or by the indigenous species in more palatable or more digestible forms. This is the chemical equivalent of 'topping' of lowland grass. The nearest hill practice to it is 'burning' which may be too severe and lead to deterioration and is restricted to a very short season of the year. This approach has the advantage of easy application on a large scale and would be promoted by more information on the sub-lethal effects of sprays and the investigation of sprays with wider spectrum of effect than the grass killers. The introduction of cattle to tackle rough herbage can lead to considerable improvement in terms of sheep keep and be equivalent in 'topping' but may be uneconomic if the cattle compete for limited capital resources or require expensive bought feed.

Similar limited improvement can be achieved by fencing into large paddocks or by the application of low dressings of limestone and slag. In Table 1, 10 cwt/ac slag resulted in improved grazing eight years after application. Application of low rates of limestone and slag (3) have resulted in no botanical changes but the herbage has higher Ca and P_2O_5 content many years later. Heavy dressings of ground limestone and slag are desirable for the introduction and maintenance of swards based on *Lolium perenne/Trifolium repens*. Herbage production on such areas can be high (1, 2) reaching 50% of that attained on lowland even on land within the context 'vast acreages'. Livestock output from hill land is theoretically capable of increase but whilst it is unrealistic to expect intensive hill farming to be economically sound when lowland farming is just scraping by.

Nevertheless, the combination of improvement of vast acreages at low cost per acre combined with intensive production from carefully selected spots is sufficiently promising to justify continued investigation of the use of herbicides.

References

1. HUNT, I.V. (1962). The persistence and productivity of grasses on upland peat. West of Scot. Grassland Husbandry Dept. Expt. Rec. No. 4, 34 pages.

2. HUNT, I.V. (1964). Comparative productivity of herbage varieties on upland peat. J. Brit. Grassl. Soc., 19, 55-61.

3. ROBERTSON, R.A. and NICHOLSON, I.A. 1961. The response of some hill pasture types to lime and phosphate. J. Brit. Grassl. Soc., 16, 117-125.

SWARD RENOVATION. SOME N.A.A.S. EXPERIENCE 1963 - 1964

S. A. Evans
National Agricultural Advisory Service

Summary Nineteen trials on lowland swards using dalapon and/or paraquat as a pre-treatment for sward renovation by oversowing are reported. Results were variable and an improvement in the sward not always obtained. Cultivations were usually essential for a satisfactory establishment of broadcast grass and clover seed. The occurance of unsown grasses in the new sward was generally reduced by cultivations and further reduced by the use of a herbicide but not eliminated.

INTRODUCTION

The N.A.A.S. have been carrying out trials with herbicides as an aid to pasture improvement for several years. The first trials of this nature reported in this country were carried out by the N.A.A.S. in 1954 using TCA (Davies and Evans, 1954) and subsequently several reports have been given on dalapon, used in a similar manner, at previous British Weed Control Conferences (Ormrod 1958, 1960; Rowlands 1960; Jones 1962). The recent introduction of paraquat stimulated further trials and this report briefly summarises some of them.

METHOD AND MATERIALS

Fifteen trials are reported which were carried out almost entirely on lowland-type swards where there was no appreciable "mat". The chemical treatments were 2 lb paraquat ion and $7\frac{1}{2}$ lb dalapon a.e. per acre. Swards in which broad-leaved weeds were present to any extent were pre-treated with 2,4-D.

The system of using the herbicides was either

a) spray in July/August 1963 with paraquat; follow in about three weeks with various cultivations of contrasting types for comparison and sow the grass and clover seed. (8 trials)
b) spray in September/mid-October 1963 with paraquat and dalapon; in the following spring (1964) carry out various cultivations of contrasting types for comparison and sow the grass and clover seed. (11 trials)

The contrasting cultivations were generally of three types (i) no cultivation (ii) a light ("intermediate") cultivation and (iii) a heavy cultivation. The light cultivation usually consisted of harrowing several times and the heavy cultivations were often rotary cultivation but sometimes simply the use of heavy disc harrows. The seeds mixture sown was perennial ryegrass, a little timothy and white clover (S100 or New Zealand). The land was usually harrowed or rolled after broadcasting the seed.

The treatments were either in single or duplicated plots. In the case of duplicate plots, the results given later are a mean of the pairs of plots.

Table 1(a)

Assessment of swards in summer 1964, twelve months after herbicide treatment in July/August 1963

(No. of hits per 100 points recording the first hit of each species at each point)
a = no cultivations b = intermediate cultivation c = heaviest cultivation

	EAST MIDLAND REGION				EAST REGION			GLOS. S.W. REGION					
	Paraquat				Paraquat		No herbicide	Paraquat			No herbicide		
	a	b	c	Original sward	a	c	c	a	b	c	a	b	c
White clover	25	30	33	0	4	2	8	1	3	4	0	0	0
Perennial ryegrass	25	52	85	32	38	92	150	32	32	36	22	26	12
Other useful grasses	10	3	7	18	8	0	28	5	11	13	8	18	14
Less-useful grasses	79	59	29	119	222*	234	154	39	37	34	54	38	50
Broad-leaved weeds	4	4	4	0	2	6	6	24	19	16	16	18	24

East Midland Region: b = pitchpole harrow; c = rotary cultivation

East Region: c = rotary cultivation; *large meadow foxtail

Glos. S.W. Region: b = drag harrows; c = discs (These figures have been reduced to a basis of 100 for each treatment).

Table 1(b)

Assessment of swards in summer 1964, twelve months after herbicide treatment in July/August 1963

(No. of hits per 100 points, recording the first species hit at each point)

a = no cultivations b = intermediate cultivation c = heaviest cultivation

	NORTHERN REGION						TRURO, S.W. REGION							CARMARTHEN, WALES					
	Paraquat			No herbicide			Paraquat			No herbicide			Original sward	Paraquat			No herbicide		
	a	b	c	a	b	c	a	b	c	a	b	c		a	b	c	a	b	c
White clover	6	15	6	5	5	4	20	3	0	0	0	0	0	8	11	5	1	5	5
Perennial ryegrass	23	54	48	40	50	48	42	86	95	27	79	71	39	1	41	58	44	21	17
Other useful grasses	3	13	10	6	3	3	4	1	0	11	1	1	7	0	16	13	2	0	0
Less-useful grasses	34	16	27	47	40	39	27	10	3	62	17	21	54	65	25	19	49	72	75
Broad-leaved weeds	20	3	9	3	3	7	3	0	0	0	0	0	0	14	1	5	3	2	3

Northern Region: b = harrows c = discs

Truro, S.W. Region: b = discs c = rotary cultivation

Carmarthen, Wales: b = harrows c = rotary cultivation

	COTHERIDGE, WEST MIDLAND REGION						WADBOROUGH, WEST MIDLAND REGION								
	Paraquat		Dalapon		No herbicide		Paraquat			Dalapon[x]			No herbicide		
	b	c	b	c	b	c	a	b	c	a	b	c	a	b	c
White clover	1	1	2	1	2	1	0	0	1	1	0	1	4	4	2
Perennial ryegrass	52	73	64*	53*	52	48	73*	97	98	54*	98	92	16	83	94
Other useful grasses	1	1	0	1	2	1	0	0	0	3	1	1	0	3	0
Less-useful grasses	37	14	17	38	36	36	24	2	1	17	3	9	71	10	4
Broad-leaved weeds	3	6	5	4	1	4	2	0	0	15	1	2	8	0	0

Cotheridge, West Midland Region: b = discs c = rotary cultivation

Cultivation 3 weeks and 2 months after paraquat and dalapon respectively. Reseed 2 months after spraying.

*more consolidated after discs than rotary cultivation

Wadborough, West Midland Region: b = discs c = rotary cultivation

*said by recorder to be an overestimation of establishment of ryegrass

[x]sown 4-5 weeks after spraying

Table 1(b) (continued)

Assessment of swards in summer 1964, twelve months after herbicide treatment in July/August 1963

(No. of hits per 100 points, recording the first species hit at each point)
a = no cultivation   b = intermediate cultivation   c = heaviest cultivation

DENBIGH, WALES

	Paraquat			No herbicide			Original sward
	a	b	c	a	b	c	
White clover	18	14	14	19	20	21	20
Perennial ryegrass	8	19	27	15	18	29	14
Other useful grasses	0	3	6	0	0	2	0
Less-useful grasses	23	20	18	47	50	29	42
Broad-leaved weeds	48	41	34	19	12	19	24

b = harrows   c = rotary cultivation

Table 2(a)

Assessment of swards in summer 1964 approximately nine months after herbicide treatment in September/October 1963

(No. of hits per 100 points, recording the first species hit at each point)
a = no cultivation   b = intermediate cultivation   c = heaviest cultivation

PAR, S.W. REGION

	Paraquat		Dalapon		No herbicide		Original sward
	b	c	b	c	b	c	
White clover	20	19	21	21	0	8	18
Perennial ryegrass	72	76	31	58	18	60	16
Other useful grasses	3	0	2	0	8	0	18
Less-useful grasses	3	0	18	9	74	20	42
Broad-leaved weeds	1	4	28	10	0	14	4

b = drag harrows   c = rotary cultivation

Table 2(a) (continued)

Assessment of swards in summer 1964 approximately nine months after herbicide treatment in September/October 1963

(No. of hits per 100 points, recording the first species hit at each point)
a = no cultivation b = intermediate cultivation c = heaviest cultivation

NORTHERN REGION

	Paraquat a	Paraquat b	Paraquat c	Dalapon a	Dalapon b	Dalapon c	No herbicide a	No herbicide b	No herbicide c
White clover	12	14	12	7	11	8	4	8	4
Perennial ryegrass	34	27	47	17	15	24	31	35	37
Other useful grasses	2	3	4	1	2	1	1	0	2
Less-useful grasses	40	37	23	70	63	55	61	55	53
Broad-leaved weeds	5	18	10	5	11	8	1	1	5

b = harrows c = discs

DEVON, S.W. REGION

	Paraquat a	Paraquat b	Paraquat c	Dalapon a	Dalapon b	Dalapon c	No herbicide a	No herbicide b	No herbicide c
White clover	7	5	6	8	5	6	1	6	10
Perennial ryegrass	9	62	71	10	48	82	2	5	60
Other useful grasses	24	4	2	23	10	0	49	52	5
Less-useful grasses	54	23	14	39	33	7	45	33	21
Broad-leaved weeds	5	5	6	20	4	3	5	4	2

b = harrows c = rotary cultivation

CARMARTHEN, WALES

	Paraquat a	Paraquat b	Paraquat c	Dalapon a	Dalapon b	Dalapon c	No herbicide a	No herbicide b	No herbicide c
White clover	8	3	4	7	1	2	23	15	4
Perennial ryegrass	5	3	33	3	3	47	5	21	29
Other useful grasses	0	0	8	0	0	3	0	0	5
Less-useful grasses	66	87	43	67	64	44	68	57	54
Broad-leaved weeds	20	7	11	23	32	4	4	7	7

b = harrows c = rotary cultivation

DENBIGH, WALES

	Paraquat a	Paraquat b	Paraquat c	Dalapon a	Dalapon b	Dalapon c	No herbicide a	No herbicide b	No herbicide c	Original sward
White clover	10	5	4	15	17	6	15	20	19	20
Perennial ryegrass	4	8	25	2	5	30	29	13	17	14
Other useful grasses	4	2	9	0	0	8	2	0	0	0
Less-useful grasses	26	24	25	14	27	28	36	49	54	42
Broad-leaved weeds	24	42	30	44	26	19	18	18	10	24

b = harrows c = rotary cultivation

Table 2(b)

Assessment of swards in summer 1964 approximately nine months after herbicide treatment in September/October 1963

(No. of hits per 100 points recording the first hit of each species at each point)
a = no cultivation b = intermediate cultivation c = heaviest cultivation

EAST MIDLAND REGION

	Paraquat		Dalapon		No herbicide	Original sward
	b	c	b	c	c	
White clover	41	36	32	43	33	0
Perennial ryegrass	33	77	62	78	72	32
Other useful grasses	9	12	19	11	9	18
Less-useful grasses	65	28	62	41	70	107
Broad-leaved weeds	3	9	2	6	5	0

b = pitchpole harrow
c = rotary cultivation

EAST REGION

	Paraquat		Dalapon		No herbicide	Original sward
	a	c	a	c	c	
White clover	68	36	70	58	20	1.8
Perennial ryegrass	38	194	36	140	94	0
Other useful grasses	22	30	18	40	18	2
Less-useful grasses	208*	98	200*	138*	260*	188
Broad-leaved weeds	14	8	8	20	4	0

c = rotary cultivation
*largely meadow foxtail

EPNEY, S.W. REGION

	Paraquat			Dalapon			No herbicide		
	a	b	b'	a	b	b'	a	b	b'
White clover	76	72	82	68	68	66	66	60	62
Perennial ryegrass	56	56	28	50	58	72	12	22	34
Other-useful grasses	18	8	20	26	56	32	56	54	34
Less-useful grasses	122*	92*	76*	88≠	84≠	84≠	190≠	156≠	122≠
Broad-leaved weeds	28	28	22	18	12	10	6	12	4

b = light harrows seed drilled
b'= light harrows seed broadcast
*mainly meadow foxtail
≠mainly rough-stalked meadow grass and bent

TAYNTON, S.W. REGION

	Paraquat			Dalapon			No herbicide		
	a	b	b'	a	b	b'	a	b	b'
White clover	28	26	64	20	16	36	26	44	24
Perennial ryegrass	10	32	76	14	18	36	20	18	20
Other-useful grasses	14	28	28	14	20	16	42	26	26
Less-useful grasses	52	56	26	84	40	54	62	56	62
Broad-leaved weeds	38	36	60	26	44	36	12	32	16

b = light harrows seed drilled
b'= light harrows seed broadcast

Assessments of all the trials were carried out in the summer of 1964 by means of a point quadrat, recording either the first species hit or the first hit of each species at any one point. The first method indicates the contribution of each species to the ground cover; the second method is probably preferable in these trials as it indicates the proportion of ground covered by each species.

RESULTS

Results of the point quadrat assessments at each trial are summarised (as the mean number of hits per 100 points) in Tables 1 and 2. The term "other useful grasses" used in these tables implies one or more of the following species: timothy, cocksfoot and meadow fescue. The "less-useful grasses" were various other species that were unsown. Individual plant species have been recorded at nearly all sites but the details are not given here. The cultivations used in preparation for sowing the seeds are briefly indicated for each site.

In many trials most treatments did not bring about substantial improvement in the sward as judged by the amount of ryegrass, and other useful grasses and clover present.

Cultivations

In practically all trials the amount of ryegrass in the new sward increased with the increasing severity of the cultivations before sowing the seed. Where no cultivations at all were carried out establishment was often very poor.

Herbicides

In hardly any case did the use of a chemical before cultivating lead to a better establishment of ryegrass and clover, but herbicides often led to a lower amount of the unsown "less-useful" grasses in the new sward.

DISCUSSION

The best swards, i.e. those with the most ryegrass and the least unsown species, were produced by a combination of fairly drastic cultivation and the use of a herbicide. To obtain an adequate establishment of broadcast grass and clover seed adequate cultivations were essential and these cultivations in themselves killed some of the old sward. Herbicides have improved the kill but they have not, with one exception, eliminated unsown species and the reduction compared to the unsprayed plots, was often not marked. This raises the question of the value of a herbicide. Does the small reduction in unsown species justify the cost of a herbicide? Would a little extra cultivation be a cheaper way of reducing the unsown species?

If there are no supplementary advantages to using a herbicide, such as increased speed or ease of subsequent operations, these trials suggest that on lowland swards where there is no impediment to surface cultivations there may be little advantage in using a herbicide.

Acknowledgments

These trials were carried out by N.A.A.S. Regional Grassland Officers and acknowledgment is made to the considerable amount of work undertaken by Messrs. T. F. Blood, R. P. Davies, T. H. Davies, W. E. Hughes, H. W. Roberts and A. Rowlands.

References

DAVIES, J. and EVANS, S. A. (1954) Sward Destruction by TCA. Proc. 2nd British Weed Control Conference 1954 205-212.

JONES, J. (1962) Dalapon as an Aid to Sward Renovation. Proc. 6th British Weed Control Conference 1962 65-74.

ORMROD, J. (1958) Field Experiences with Dalapon in Re-seeding Difficult Land. Proc. 4th British Weed Control Conference 1958 241-244.

ORMROD, J. (1960) The Use of Chemicals in the Renovation of Difficult Swards in the East Midlands of England. Proc. 5th British Weed Control Conference 1960 151-156.

ROWLANDS, A. (1960) Improvement Studies on _Festuca/Nardus_ and _Calluna/Molinia_ Areas. Proc. 5th British Weed Control Conference 1960 165-170.

FIELD FACTORS INFLUENCING PASTURE RESEEDING AFTER PARAQUAT

T. Gleeson

Grassland Nutrition and Ecology Department, An Foras Taluntais, Johnstown Castle, Wexford, Ireland

Summary In some preliminary investigations on surface seeding with the aid of the herbicide paraquat, cultivation and sowing were successfully attempted on several dates from late March to late July in conditions of adequate soil moisture; the possibility of using rates of paraquat as low as ½ lb was indicated. In more extensive trials, though rotovation proved superior to any other method of cultivation, satisfactory establishment was achieved with light cultivators where surface litter was reduced.

INTRODUCTION

Some preliminary investigations were carried out at Johnstown Castle on the optimum time for pasture reseeding with the aid of paraquat (Experiments 1, 2) and the activity of paraquat over the winter period (Experiment 3), but as unfavourable soil and herbage conditions are the principal obstacles to this technique (Davies et al 1960) the main effort was devoted to elucidating these factors in the field (Experiment 4). Greater emphasis was placed on surface harrowing as rotovation limits the technique to arable soils.

METHODS AND MATERIALS

All studies were made with randomised block field experiments. Paraquat[1] was applied with a tractor sprayer, with a 16 ft boom, in 45 gal water/acre in Experiments 1, 2, 4, and with a knapsack sprayer in 120 gal water/acre in Experiment 3. All plots in Experiments 1, 2, 4 were sown with 20 lb N. Z. permanent pasture perennial ryegrass and 3 lb N. Z. white clover per acre, and fertilised with 23 lb N, 36 lb P and 56 lb K per acre applied with the seeds. Botanical analyses were expressed as ground cover percent i.e. the mean of ten 1 ft^2 quadrats. Soil temperature and rainfall were taken from the meteorological records at Johnstown Castle.

Experiment 1

This experiment was carried out in 1963 on an old sward grazed to 2 in. on a friable fertile loam soil imperfectly drained. There were seven treatments consisting of cultivation and sowing at six dates: 29/3; 30/5; 29/6; 27/7; 30/8; 26/9; after paraquat application (1½ lb ion/ac.) 7 - 10 days previously. A control plot was fertilised only at the first date. Plot size was 0.025 acres. There were three replications.

Plots were disc harrowed until over 70% of the soil was exposed. Seeds and fertiliser were harrowed-in with a spiked chain harrow. All plots were grazed periodically. They were closed up at the end of November until dry matter yields were measured on 3/6/64.

Experiment 2

This experiment was carried out over the 1963/64 winter period on an old sward grazed very bare with sheep until November on a fertile freely drained sandy loam soil. Paraquat (1½ lb ion/ac) was applied on 7/11/63, 18/1/64 and 19/3/64. All plots were sown on 2/4/64. Plot size was 0.025 acres. There were two replications. As cultivation was easy a spiked chain harrow only was used. Seeds and fertiliser were harrow-

[1] As 'Gramoxone' W

ed-in until 90% soil exposure was achieved. Seedling development of ryegrass was very stunted so an extra dressing of 46 lb N was applied on 20/5/64.

Experiment 3

This experiment was carried out over the 1963/64 winter period on a freely drained fertile loam soil on an old pasture grazed bare at time of treatments but, because of undergrazing earlier in the season, there was an accumulation of ungrazed litter on the surface. It was a 4 x 5 factorial as follows:

1. Paraquat $\frac{1}{4}$ lb ion/ac	X	1. applied 19/12/63
2. Paraquat $\frac{1}{2}$ lb ion/ac		2. applied 18/1/64
3. Paraquat 1 lb ion/ac		3. applied 19/2/64
4. Paraquat $1\frac{1}{2}$ lb ion/ac		4. applied 19/3/64
		5. applied 18/4/64

Plot size: 0.002 acres; 2 replications

The method used to record herbicidal activity was that of Elliot (1961). No seeds were sown.

Experiment 4

This experiment was carried out in co-operation with the advisers of 24 County Committees of Agriculture in late summer and autumn of 1963 at 51 sites on farms selected by the advisers. The actual work was carried out by the farmers with their own equipment. It was originally a 4 x 2 factorial experiment as follows:

1. No herbicide	X	1. No cultivation
2. Paraquat $\frac{1}{2}$ lb ion/ac		2. Cultivation
3. Paraquat 1 lb ion/ac		
4. Paraquat 2 lb ion/ac		

Plot size: 0.25 acres: 1 replication per site

To reduce the number of treatments the $\frac{1}{2}$ and 1 lb rates of paraquat only were applied on sites cut for hay or silage (14 sites) and the 1 and 2 lb rates only on grazed sites (37 sites). At many sites the treatments were further reduced by eliminating some levels of paraquat, or cultivation, or both, thus no two treatments had the same replication. The 51 sites comprised a variety of herbage, soil, and management conditions and were classified as follows:

Mineral soils freely drained	28 sites
Mineral soils imperfectly drained	3 sites
Peat soils freely drained	9 sites
Peat soils imperfectly drained	11 sites

Spraying was performed on various dates from July 10 to August 30. Cultivation and sowing were carried out 2-4 weeks later (during August and September at the majority of sites). The type of cultivator used was decided by the farmer. Detailed records were made of all operations and conditions under which they were performed.

RESULTS

Experiment 1

Though paraquat gave a satisfactory kill on all dates, slight improvement with later dates of application was observed. Similar results have been reported by Douglas and McIlvenny (1962). The main results are summarised in Table 1.

The higher number of discings required during mid-summer was most likely due to the more compact and less moist soil and the greater litter density from the treated sward during this time. Though there was adequate soil moisture on all sowing dates (Fig. 1), seedlings emerged within three weeks on June and July plots only.

Table 1

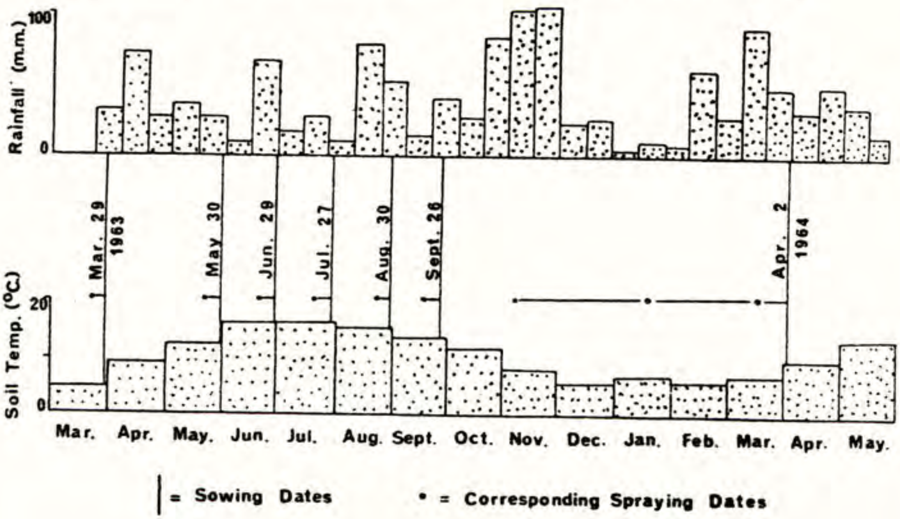
Results of Experiment 1

Spraying date 1963	Sowing date 1963	Discings required to give 70% soil exposure	Botanical composition (% ground cover 20/5/'64) Lolium perenne	Poa trivialis	Holcus lanatus	Festuca rubra	Other grasses	Trifolium repens	Other species	Dry matter yields 3/6/64 lb/ac
22/3	29/3	3	41.3	23.3	3.8	0.0	2.3	24.3	5.0	4521
20/5	30/5	5	39.7	14.3	3.0	1.0	0.3	35.7	6.0	4441
19/6	29/6	6	46.3	25.3	2.7	0.7	0.0	17.0	8.0	3752
20/7	27/7	8	30.6	26.0	2.7	3.7	0.7	30.6	5.7	3676
23/8	30/8	7	26.3	28.3	1.3	1.7	2.0	28.4	12.0	3371
18/9	26/9	6	20.7	31.3	0.0	0.0	0.7	39.3	8.0	2782
Control	-	-	12.6	23.0	18.7	7.7	11.3	21.7	5.0	4262
F. test[1]	-	-	***	N.S.	***	N.S.	N.S.	**	N.S.	*
L.s.d. (P= 0.05)			10.7	-	11.6	-	-	8.8	-	995

[1] * $P < 0.05$ ** $P < 0.01$ *** $P < 0.001$ N.S. $P > 0.05$

FIG. 1

Spraying and Sowing Dates for Experiments 1. & 2. in Relation to Total Fortnightly Rainfall and Mean Monthly Soil Temperatures at 2 in.



The seedlings of August, and especially September, sown plots suffered from surface waterlogging, a noted fault of this technique on heavy soils (Bailie, 1963). Clover seedlings were observed to emerge on all plots but with the exception of the earlier sowing dates, probably contributed little to the final sward. The higher dry matter yields from longer sown plots indicate that sward development is slow with surface seeding, the two early sown plots, only, being better than the old sward.

Experiment 2

Paraquat gave an excellent kill on the bare sward on the three dates of application, though the January application took three weeks to take effect. At sowing time in April, March sprayed plots were completely bare; a network of clover stolons covered 10% of January and 20% of November sprayed plots. There were some weeds, mainly Rumex acetosa, especially in the latter plots. The relevant results are shown in Table 2.

Table 2
Results of Experiment 2

Spraying date	No. of harrowings to give 90% soil exposure	Botanical composition % ground cover 19/6/'64							Dry matter yields lb/ac 1/7/64
		Lolium perenne	Agrostis tenuis	Poa trivialis	Holcus lanatus	Other grasses	Trifolium repens	Other species	
7/11/63	4	33.5	13.5	0.5	0.0	0.0	34.8	17.7	2865
18/1/ 64	4	37.5	9.0	1.0	0.5	0.3	37.2	14.5	2493
19/3/ 64	4	43.2	9.0	0.0	1.0	0.0	33.8	12.2	2710
F. test	-	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Surrounding control		2.0	17.0	24.0	16.0	12.0	26.0	3.0	-

As the soil was moist (Fig. 1) and almost completely free of plant litter, four runs of a spiked chain harrow were sufficient to give 90% soil exposure, no difference being noted between spraying dates. Though seedlings emerged within three weeks of sowing they remained stunted and tillering was poor, but there was an immediate response in tillering and growth to the extra nitrogen applied on 20/5/64.

Experiment 3

The activity of the four rates of paraquat on different dates from December, 1963, to April 1964, is shown in Fig. 2. The relevant soil temperatures and rainfall are shown in Fig. 1. The applications of paraquat in December, January and February were slower in action and apparently more effective at low rates than applications in March and April. However, the long 'dead' phase of the early sprayings did not prolong into the growing season, recovery coinciding with spring growth in early March. A smaller residual effect on the herbage may be the cause of the smaller differences between rates of paraquat on the regrowth of the December plots. The mean botanical composition of all treatments on 21/7/64 gives an indication of the selective effect of paraquat on recovery (Table 3), most of the grass recovery being Agrostis tenuis.

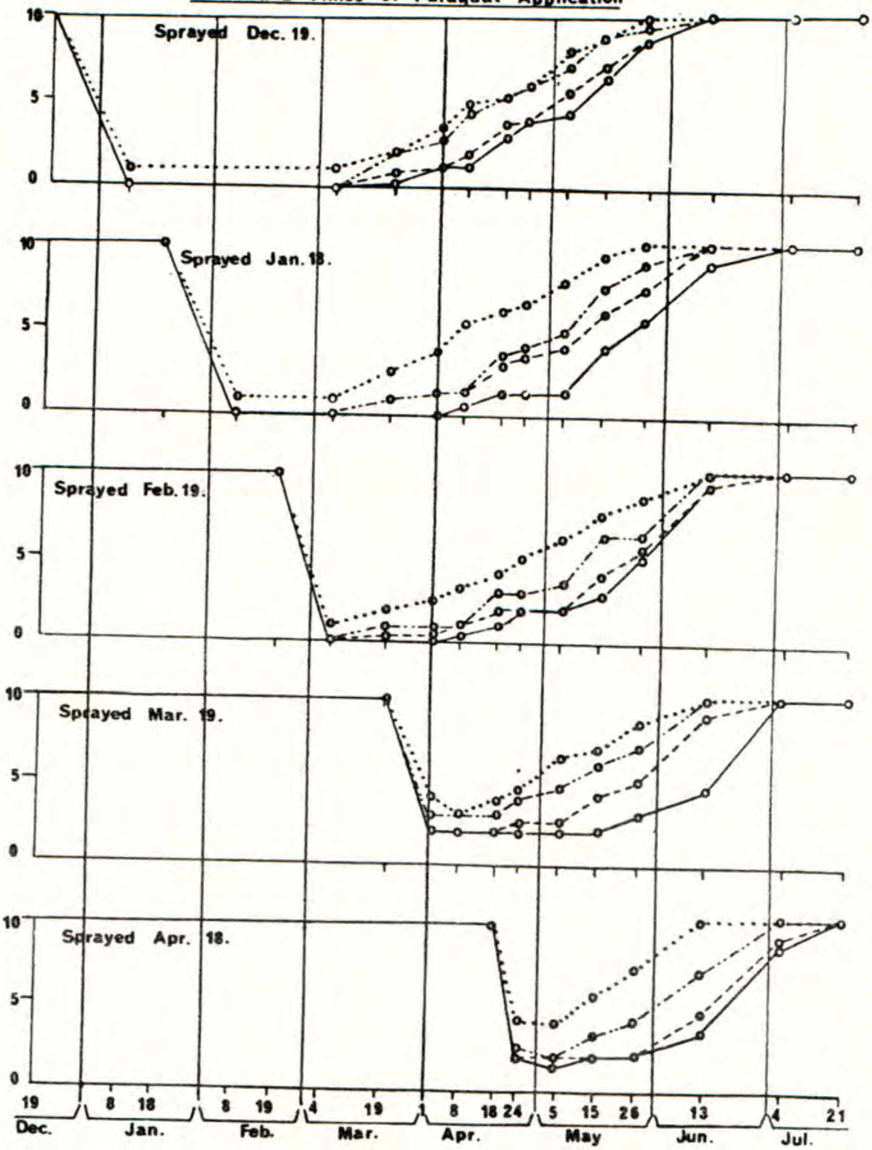
Experiment 4

Because of the large number of sites involved only visual estimates of the results could be made. A rating on the scale 0, $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, was assigned to herbicidal effect (0 = no effect, 1 = complete kill); degree of cultivation achieved[1] (0 = no establishment, 1 = good ryegrass/cover sward). The ratings were made by the author at the sites during October and November.

[1] One cultivation rating only, i.e. the cultivation achieved on sprayed plots, was made for each site.

FIG. 2

Rates and Times of Paraquat Application



0 = No green foliage

10 = Foliage similar to untreated sward

o·······o = 0·25 Lb. Paraquat / Ac.

o-·-·-o = 0·5 " " "

o- - - -o = 1·0 " " "

o———o = 1·5 " " "

Table 3

Mean botanical composition of treatments of Experiment 3
(% ground cover 21/7/'64)

	Control	Treatments
Agrostis tenuis	28	46
Poa trivialis	5	0
Holcus lanatus	35	6
Festuca rubra	5	1
Other grasses	5	0
Trifolium repens	7	24
Other species	15	23

In general a herbicide and cultivation were essential to obtain good establishment (Table 4), but the incidence of failure was high even with these treatments. These poor results were mainly due to field conditions.

Table 4

Distribution of plots on establishment ratings and mean establishment ratings for treatments of Experiment 4

Paraquat lb/ac	Total plots	Establishment rating 0	¼	½	¾	1	Mean establishment rating
(a) Uncultivated							
0	30	21	8	1	0	0	0.08
½	8	5	3	0	0	0	0.09
1	31	9	15	6	0	1	0.25
2	25	8	11	6	0	0	0.23
(b) Cultivated							
0	32	10	10	10	0	2	0.30
½	10	2	1	1	3	3	0.60
1	42	5	2	6	15	14	0.68
2	35	4	4	3	12	12	0.67

Chi^2 (a) $P < 0.05$ (b) $P < 0.01$[1]

Factors which influenced herbicidal activity: Though better herbicidal activity was obtained where the higher rates of paraquat were used, there was little difference between the 1 lb and 2 lb rates (Table 5). All rates were better on swards with short green grass tillers as shown by the effect of pre-treatment (Table 6).

As in the experiments already described paraquat exerted a selective influence on the recovery of unsown species. Trifolium repens, Festuca rubra, and broadleaved weeds were noticeably resistant. Bad rush reinfestation occurred at two wet sites.

[1] The Chi^2 tests for the tables of Experiment 4 are of dubious validity as many expected class frequencies are too small, but were partially corrected for in the analyses by grouping some classes (Fisher 1950).

Table 5

Distribution of plots on herbicidal ratings of paraquat, and mean herbicidal ratings for three rates of paraquat (Experiment 4)

Paraquat lb/ac	Total plots	Establishment rating					Mean establishment rating
		0	¼	½	¾	1	
½	13	0	0	4	4	5	0.77
1	48	0	1	3	15	29	0.88
2	44	0	0	6	8	30	0.89

Chi^2 $P < 0.05$

Table 6

Distribution of plots on herbicidal ratings of 1 lb of paraquat, and mean ratings for three pre-treatments (Experiment 4)

Pre-treatment	Total plots	Herbicidal rating					Mean establishment rating
		0	¼	½	¾	1	
Undergrazed	24	0	1	2	9	12	0.83
Cut for hay/silage 2 - 4 weeks before spraying	15	0	0	1	6	8	0.87
Grazed bare	9	0	0	0	0	9	1.00

Chi^2 $P < 0.01$

Factors which influenced cultivation: The distribution of cultivation ratings produced by the cultivators used (Table 7) indicate the superiority of the rotovator. It was the only implement to produce a good seedbed irrespective of soil conditions. Disc and curved tined harrows were quite good on level soil free of litter, though the latter type tended to dig up sods. Zig-zag (pin) harrows were mostly too light; so also was the spiked chain harrow, but it had the advantage of being flexible over surface undulations. In the case of harrowing at least six runs were required to produce sufficient scarification for sowing.

Table 7

Distribution of cultivators on cultivation ratings, and mean cultivation ratings for five cultivators (Experiment 4)

Cultivator or Harrow	No. used	Cultivation rating					Mean cultivation rating
		0	¼	½	¾	1	
Rotovator	14	0	0	0	3	11	0.95
Disc	10	1	0	0	5	4	0.78
Curved tined	10	1	3	2	3	1	0.50
Zig-zag (pin)	16	5	3	3	4	1	0.39
Spiked chain	1	0	0	0	1	0	0.75

Chi^2 $P < 0.01$

By far the greatest obstacle to surface cultivation was an accumulation of moss and ungrazed herbage on the surface i.e. surface mat (Table 8).

Table 8

Distribution of sites on cultivation ratings (excluding rotovation) and mean cultivation ratings for two sward categories

(Experiment 4)

Sward type	Total sites	Cultivation rating					Mean cultivation rating
		0	¼	½	¾	1	
Bare: no moss or excess litter	25	0	4	4	11	6	0.69
Surface mat of moss or litter	12	7	2	1	2	0	0.21

Chi^2 $P < 0.01$

In general peats were easier to cultivate than the drier more compacted mineral soils, but many peats had a thick litter layer.

Factors which influenced establishment: In general the establishment of ryegrass seedlings was better than that of clover, but the recovery of indigenous clover compensated for the latter.

Seedling establishment was affected by the degree of cultivation (Table 9) and herbicidal effect (Table 10).

Table 9

Distribution of cultivation ratings on establishment ratings (1 lb paraquat plots only) and mean establishment ratings

(Experiment 4)

Cultivation rating	Number of plots	Establishment rating					Mean establishment rating
		0	¼	½	¾	1	
0	4	4	0	0	0	0	0.00
¼	4	0	1	1	1	1	0.63
½	5	0	1	1	2	1	0.65
¾	15	1	0	3	9	2	0.68
1	14	0	0	1	3	10	0.91

Chi^2 $P < 0.01$

Table 10

Distribution of herbicidal ratings on establishment ratings, and mean establishment ratings on cultivated plots

(Experiment 4)

Herbicidal rating	Number of plots	Establishment rating					Mean establishment rating
		0	¼	½	¾	1	
0 (No herbicide)	32	10	10	10	0	2	0.30
½	10	1	1	2	6	0	0.58
¾	32	7	4	12	5	4	0.46
1	47	3	1	3	14	26	0.81

Chi^2 $P < 0.01$

At a few peat sites with sparse vegetation, good establishment was achieved with no herbicide and indifferent cultivation. There was very good establishment on one heavily matted peat, where the vegetation was burned off but no cultivation carried out.

Not only was surface litter responsible for poor cultivation, but it also directly inhibited seedling establishment, which was more obvious on uncultivated plots (Table 11). To what extent this effect was due to chemical residue in the trash is not clear, but the 1 lb rate gave better establishment than the 2 lb rate of paraquat at two sites. At one peat and one sandy site, no seedlings appeared on sprayed plots for no apparent reason other than toxicity. As the majority of sites were sown 3-4 weeks after spraying it was not possible to record any effect of interval between spraying and sowing. Though impeded drainage had no marked effect on establishment, it resulted in slower seedling development and tillering, and at one site appeared to enhance slug damage.

Table 11

Distribution of sites on establishment ratings, and mean establishment ratings for two sward categories on uncultivated plots (Experiment 4)

Sward type	Total sites	Establishment rating					Mean establishment rating
		0	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	1	
Bare: no moss or excess litter	24	2	15	6	0	1	0.32
Surface mat of moss or litter	9	9	0	0	0	0	0.00

Chi^2 $P < 0.01$

DISCUSSION

The results of Experiment 1 indicate that pastures can be surface reseeded from spring to early August in our climate, but where surface cultivation is attempted one may have to decide between better herbicidal effect and more difficult cultivation as the season advances. A possibility based on the results of Experiment 3 would be to apply $\frac{1}{4}$ to $\frac{1}{2}$ lb of paraquat before commencement of spring growth and to re-spray any re-growth, with a similar amount, before sowing later in spring.

The slower establishment of seedlings with surface cultivation is most likely due to soil compaction (Lutz 1952), but as normal rates of paraquat do not kill clover, the higher C/N ratio of the decaying root material may depress soil nitrates (Lyon et al. 1923). A nitrogen topdressing, however, as in Experiment 2 overcomes the difficulty. On this point it is interesting to compare the importance of nitrogen in sod seeding tillage crops (Hood, et al. 1964).

The importance of liming and fertiliser need scarcely be mentioned but if applied long before reseeding (Crompton 1961), by giving a more grassy closely grazed sward, they provide more suitable conditions for herbicidal activity, surface cultivation and seedling establishment.

Acknowledgments

The author wishes to record his appreciation of the advice and direction of Mr W.E. Murphy in carrying out this project. Thanks are due to Dr H.P. Allen and Mr D.B. Casey for helpful criticisms, to the many Advisers of the County

Committees of Agriculture and the many farmers who made some of the field experiments possible; to Mr J. Fenlon for technical assistance and to Irish Farm Chemicals Ltd. and the I. C. I. (Ireland) Ltd., who generously supplied the herbicides.

References

BAILIE, J. H. (1963) Reseeding without the plough. Agric. N. Irl. 38, 108-110.

CROMPTON, E. (1961) Soil Features Associated with the Development of Good Permanent Pasture in Moorland Areas. Proc. 8th Int. Grassl. Cong. 1960, 257-260.

DAVIES, G. E., HUNTER, R. F. and KING, J. (1960) Hill Pasture Improvement with Dalapon. Proc. 5th Brit. Weed Control Conf. 157-164.

DOUGLAS, G. and McILVENNY, H. (1962) The Use of Paraquat as a Sward Killer in the Improvement of Hill Communities and Lowland Pastures. Proc. 6th Brit. Weed Control Conf. 45-55.

ELLIOT, J. G. (1961) The Evaluation of Herbicidal Activity on a mixed sward. Proc. 8th Int. Grassl. Cong. 1960. 267-271.

FISHER, R. A. (1950) Statistical Methods for Research Workers (V) p. 84. Oliver and Boyd.

HOOD, A. E. M., JAMESON, H. R. and COTTEREL, R. (1963) Destruction of Pastures by Paraquat as a Substitute for Ploughing. Nature, Lond. 197, 748-749.

LUTZ, J. F. (1952) Mechanical Impedance and Plant Growth. Agronomy 2, 43-71.

LYON, T. L., BIZZELL, J. A. and WILSON, B. D. (1923) Depressive Influence of Certain Higher Plants on the Accumulation of Nitrates in the Soil. J. Amer. Soc. Agron. 15, 457-467.

THE SELECTIVE CONTROL OF GRASSES IN PERMANENT PASTURE

J.G. Elliott and G.P. Allen
Agricultural Research Council
Weed Research Organisation
Begbroke Hill, Kidlington
Oxford. England.

PART I. THE LITERATURE.

Much of the grassland of the British Isles consists of perennial plants growing on soil that is rarely disturbed by man. The management of this land is extensive in the economic sense that it involves small inputs of labour and machinery. Any new technique of sward control should therefore fit in with these circumstances if it is to be acceptable to the grassland farmer. Chemical herbicides meet these requirements because they involve application through a relatively cheap machine to many acres in a day.

Herbicides for varying sward composition have been available in grassland for some fifteen years in the form of the growth regulator herbicides. However, these chemicals have activity confined to broad-leaved plants. Although the small number of chemicals that have been discovered to have activity against grasses have been developed for purposes of total kill, there is growing evidence in the literature to suggest that their capacity for differential action against species might be directed towards achieving changes in the botanical composition of swards. The purpose of this paper is to review what is known about these chemicals and to consider some of the factors affecting the outcome of their performance.

From a perusal of the literature it is evident that much of the information on selectivity has been derived from experiments carried out with sward destruction in mind. The experience is fairly evenly divided between New Zealand and the United Kingdom. Although it is customary to regard the respective climates of these two countries as broadly similar, important differences do exist. As herbicidal selectivity may be markedly influenced by season and climate, these differences justify the separate consideration of the results of research from the two countries.

Dalapon. New Zealand.

Thompson (1958) reported using dalapon at doses up to 5 lb/ac both at the commencement of spring growth (September) and two months later, on a pasture containing 25% ryegrass (Lolium perenne), 20% cocksfoot (Dactylis glomerata) and 35% other grasses - mainly Holcus lanatus, with Anthoxanthum odoratum, Poa spp. and Agrostis spp. Yields were taken throughout the growing season that followed. Applied in September, dalapon at 2.5 lb/ac resulted in a 23% increase in yield of perennial ryegrass at the expense of the other grasses, while 1.25 lb/ac, applied in November, caused a 31% increase in ryegrass yield. Dalapon in September initially depressed the growth of ryegrass in the 6 weeks following spraying, but total seasonal production was of such vigour as to exceed the control yield. In further work on the timing of applications of dalapon under New Zealand conditions

Thompson (1958) found the chemical to have most severe effects on ryegrass when applied in December, but very little effect when applied at 10 lb/ac to a desiccated pasture of ryegrass and white clover in February (New Zealand summer). He noted also that autumn treatments were more severe than those applied in spring and also that cocksfoot was much less tolerant of dalapon at 5 lb/ac than ryegrass, whether treated in September or November. A later paper by Thompson (1959) provides further information on the effect of rate and stage of growth of ryegrass and cocksfoot on their tolerance of dalapon. The resistance of ryegrass to dalapon at 5 lb/ac was greater when treated during a period of increasing (September or April) rather than in a period of declining growth activity (November or June). The susceptibility of young ryegrass and cocksfoot increased with increasing height and maturity. The effects of dalapon 15 lb/ac on tufted, mature cocksfoot were most severe when applied to the tallest regrowth. Bramley (1961) reported the application of dalapon at 3.7 and 7.4 lb/ac in December and March to separate blocks of Lolium perenne, Dactylis glomerata, Agrostis tenuis (browntop), Festuca rubra var. fallax (Chewing's Fescue) and Holcus lanatus. All had been established 3 years at the time of spraying. He also found ryegrass to be more resistant to dalapon than cocksfoot, but the latter was more tolerant of autumn than summer treatment. At this stage, 3 months after spraying, Festuca rubra var. fallax appeared to be rather more resistant to these rates following the December application than was cocksfoot, while the latter appeared more resistant to the March applications. Agrostis tenuis and Holcus lanatus showed very similar tolerance to dalapon at both dates but the chemical was more effective against them in autumn than in summer. Orders of species susceptibilities based on the mean of the two doses for the two dates of spraying were thus:-

	December	March
Most resistant	Lolium perenne	Lolium perenne
	Festuca rubra var. fallax	Dactylis glomerata
	Agrostis tenuis	Festuca rubra var. fallax
	Holcus lanatus	Agrostis tenuis
		Holcus lanatus
Least resistant	Dactylis glomerata	

Poa trivialis was found by Bramley to be even less resistant to dalapon than the above species. Thompson (1958) states that dalapon at rates between 2.5 - 5 lb/ac can give adequate control of Agrostis tenuis in an Agrostis/Festuca rubra var. fallax sward, when sprayed in October (New Zealand), but the fescue showed 10% survival at 10 lb/ac and later spread. Matthews (1959) indicates that Festuca rubra var. fallax absorbs dalapon more slowly than does Agrostis tenuis.

On the subject of the tolerance of white clover (Trifolium repens) to dalapon, Thompson (1958) indicates from his yield data that clovers are somewhat depressed by dalapon at rates as low as 1.25 lb/ac applied in September and November in New Zealand to an established mixed sward composed of 25% ryegrass, 20% cocksfoot, 35% other grasses and 5% broad-leaved weeds. The initial suppression caused by the 5 lb/ac rate was severe but recovery was rapid especially following early summer application. Bramley (1961) assessed the tolerance of mature white clover in a 2-year-old mixed sward 3 months after spraying dalapon at 3.7 or 7.4 lb/ac in December and March. Dalapon at 3.7 lb/ac applied in March increased the cover of Clover above that on the unsprayed control. Dalapon at 7.4 lb/ac in March appeared to cause a considerable reduction at least for the 3 months following treatment. In general, cover values were higher after December applications than March.

The main points of New Zealand experience may be summarised as follows:-

1. Dalapon has shown differential toxicity to a number of common grasses. Amongst these, perennial ryegrass has been reported from three separate sources to have shown more resistance than Agrostis tenuis. Poa trivialis has also been found more susceptible than perennial ryegrass.

2. There is evidence that the tolerance of species alters with the seasons.

3. The rate of growth, the phase of development and the quantity of foliage may all affect the reaction of a given species to dalapon.

4. White clover may initially be depressed by dalapon, but can subsequently increase its proportion in a mixed mature sward, depending on the time of year.

5. Low doses of dalapon have not only altered the composition of the sward, but have also on occasions led to increases in total sward production during the growing season following spraying.

Dalapon. The United Kingdom.

Compared with New Zealand there is rather less information, from the United Kingdom, on the selective effects of dalapon; also the types of sward involved have been rather different. Jones, L. (1961) found that Lolium perenne showed the greatest resistance to dalapon at 4 lb/ac applied in April and the least to July and September treatments. He notes, however, that the trial was carried out with various amounts of leaf present. Holroyd (1964) in trials on a pure S.23 ryegrass stand sown in rows in May 1961 and treated with dalapon + wetter applied by a logarithmic sprayer in September 1961, found that the ryegrass yield was reduced 50% by a dose of 5 lb/ac and 90% by 13 lb/ac while the same variety sown in October 1961 and sprayed in July 1962 required more than 16 lb/ac to bring about a 50% reduction. Plots established in May 1961 and sprayed in October 1962 required less than 2 lb/ac dalapon to bring about 50% reduction and only 6 lb/ac for a 90% reduction. In these trials, all assessments were made 4 months after spraying. In similar trials on S.143 cocksfoot, where sprays were applied in September 1961, 4 lb/ac was required for a 50% reduction and 16 lb/ac for a 90% reduction in yield. When sown in October 1961 and sprayed in July 1962 it required 16 lb/ac to produce a 50% reduction, but only 2 lb/ac was required when the treatments were made in October 1962. Assessments were made 4 months after spraying. Festuca rubra appeared to be more resistant than ryegrass and cocksfoot to the September 1961 spraying, and F. tenuifolia to be more resistant still. Poa annua and P. trivialis were the most susceptible species, and S.22 Lolium multiflorum, Festuca pratensis, Phleum pratense and Holcus lanatus intermediate in response. Charles and Lewis (1962) reported that in trials in which 2.2 lb/ac dalapon was applied in March and May to grass species grown in drills and in their third harvest year, there was a wide range in the reaction of various species. A better kill of most species was obtained after the March application and their figures indicated that there was an interaction between the mean relative response of the species to dalapon and the time of application. There were however, wide differences between the several varieties within a species in their response to the treatment and this was also influenced by the previous management. The mean response of a species to treatment with dalapon may thus be a function of the particular variety, or group of varieties tested.

On a mixed lowland sward Jones, L. (1962) applied dalapon at 10 lb/ac in April 1960 after having applied 2,4-D at 1 lb/ac the previous June. Assessment by yield on the 7th October, 1960, showed ryegrass, cocksfoot, Agrostis stolonifera and Poa trivialis to have been reduced by the chemical. Ryegrass was reduced by 25%, cocksfoot and Poa trivialis each by about a third and Agrostis stolonifera by 75%. White clover increased thirty-fold from a trace value in the unsprayed sward and the dicotyledonous species increased three-fold.

More recently Allen (1964) applied dalapon at 5, 10 and 15 lb/ac in July and October 1962 and early April 1963, to a lowland pasture in which Agrostis stolonifera and Poa trivialis were dominant, and Lolium perenne occupied 20%, Holcus lanatus 10%, Phleum pratense 5% and Trifolium spp. 4% of the ground cover, with a small content of dicotyledonous species also present. Considerable reductions were achieved in the amount of Agrostis stolonifera recolonising the plots after the July treatments but autumn and spring treatments resulted in strong re-establishment by this species. The most promising dose for selective work in this trial was the 5 lb/ac rate of dalapon applied in July; and in a yield assessment one year later, Agrostis yields were less than 20% of those on the unsprayed control, while yields of Lolium perenne were over three times as great as those on the control. The other grass species and clover re-established to levels similar to control but broad-leaved species particularly Ranunculus repens at least doubled their contribution to yield during the year after spraying. At this stage the sward which had been closed to grazing or cutting since herbicide treatment, had returned to a level of herbage production similar to that on the control.

Gardner (1960) working in S.W. Scotland in 1958-59 on a permanent pasture of Festuca rubra, Cynosurus cristatus, Anthoxanthum odoratum, Poa spp., Holcus lanatus, Lolium perenne and Trifolium repens, applied MCPA in autumn 1958 to remove Juncus spp. In addition, he applied 2 tons of lime and 1 ton of slag per acre. In April 1959, dalapon at 3.75 lb/ac was applied and temporarily inhibited grass growth. Herbage seed sown in a dry May did not establish. One year after spraying, plots which received dalapon and lime and slag comprised 6% Agrostis spp. and 28% ryegrass, as against 40% and 10% respectively on the unsprayed. White clover comprised 20% on sprayed plots and 16% on unsprayed.

Davies, Hunter and King (1960) reported 6 trials carried out in 1959-60, in which dalapon was used as a pre-treatment before reseeding hill pastures dominated by Agrostis spp. and Festuca spp., Nardus stricta and Molinia caerulea. The 1959 season was very hot and dry and no establishment of sown species resulted. However, assessment one year after spraying in May or August showed that Agrostis tenuis had been controlled better by the May than the August application, 2.5 lb/ac in May giving more than 50% control when assessed in May or July the following year. Plots sprayed in August showed considerable increases in Agrostis tenuis between a May and a July assessment the following year. Though initial kills, where 5 lb/ac had been used, looked promising, Festuca ovina was more resistant to treatment in May than in August and required 10 lb/ac in August to bring about any large and permanent reduction. Molinia caerulea and Nardus stricta were both controlled by dalapon at 5 lb/ac, though Molinia control was poor following early treatment in May in one trial. Species resistant to dalapon at 10 lb/ac were Holcus spp., Anthoxanthum odoratum and Deschampsia flexuosa.

Jones, J. (1962) used dalapon at 3.75 and 7.5 lb/ac to assist in sward improvement without oversowing by selectively checking undesirable grasses. Nardus stricta and Deschampsia caespitosa were effectively controlled, while Agrostis spp. and Festuca spp., though suppressed, were less susceptible than the former species to sprayings in July and September. The results of preliminary trials by Jones suggested that as little as 1.5 lb/ac dalapon will control Nardus stricta in Agrostis/Festuca swards. Lawson (1962) reported that the treatment, of land dominated by Nardus and Molinia with dalapon 3.75 and 4.5 lb/ac, brought about considerable changes in sward composition. Where soil fertility remained unchanged, better species could not exploit the temporary vacuum left by the death of the grasses and the sward quickly reverted to its original balance, but where lime or lime and phosphate were applied in addition to dalapon, species such as Agrostis and Festuca colonised the ground. Lime and phosphate plus dalapon brought about much quicker improvement than the same quantity of lime and phosphate alone. Lime alone brought about a decrease in the proportion of Nardus in the sward; the effect of dalapon was to accelerate this process. Where grasses were not able to spread quickly and cover the bare ground left after spraying, the lime and phosphate treated sward was taken over by broad-leaved species.

On the basis of results from three British environments, Fryer and Chancellor (1958) tentatively placed a number of species in the following order of increasing susceptibility to dalapon applied in August and September 1957.

1. Poa trivialis
2. Cynosurus cristatus, Holcus lanatus, Lolium perenne
3. Agrostis tenuis
4. Festuca rubra
5. Agrostis canina
6. Molinia caerulea, Anthoxanthum odoratum, Nardus stricta and Deschampsia caespitosa.

From the work done in the United Kingdom, a number of conclusions can be drawn and it is interesting to note their similarity to the conclusions drawn from experience in New Zealand. The main conclusions from United Kingdom experience were as follows:-

1. Common grass species differed in their responses to dalapon. Perennial ryegrass and Festuca spp. were relatively resistant, while Nardus stricta, Molinia caerulea, Deschampsia caespitosa and Agrostis stolonifera were susceptible to quite low doses.
2. The time of season at which the dalapon was applied and the age of the plants when treated affected species' reaction.
3. Within a species, strains with contrasting past managements reacted differently to the chemical.
4. White clover showed an ability to survive dalapon application and to increase its content in the sward after the accompanying grasses had been suppressed.

Paraquat. The United Kingdom.

Field work on paraquat commenced in 1960. Its development as a selective herbicide in a grassland context follows the same path as that of dalapon, for paraquat too, was seen initially as a grass killer.

Some of the early field tests of paraquat, were carried out by the Weed Research Organisation, in 1960, (Fryer 1962). Established rows of perennial and Italian ryegrass, timothy, cocksfoot and meadow fescue were sprayed in August with paraquat at 0.5, 1 and 2 lb/ac. Assessments 2 months later showed that whereas cocksfoot was much the most resistant, perennial ryegrass, timothy and meadow fescue were also comparatively tolerant, while Italian ryegrass was virtually eliminated by 0.5 lb/ac. Further work by Holroyd in 1961-62, reported by Fryer (1962) in which a logarithmic sprayer was used to treat a wider range of grasses grown in rows, showed the same orders of susceptibility; however, the addition of the wetting agent (0.1% Agral 90) to the spray solution was estimated to have increased phyto-toxicity by a factor of 2. Exceptions to this were cocksfoot, (a factor of x 1.5) and Festuca rubra (a factor of x 2.5). This suggested that a wetting agent not only increases the overall activity of paraquat but is potentially capable of enhancing selectivity. Furthermore, Holroyd's trials indicated that time of application was important and that, for example, less chemical was required to give a 50% reduction 4 months after an October than after a July application.

Working on lowland grassland, Jones, L. (1962) used paraquat at 1.8 lb/ac plus wetter in April 1960 on a mixed sward to which 2,4-D at 1 lb/ac had been applied the previous June. Yields were assessed in October 1960. White clover had increased by a factor of x 30, cocksfoot by x 4.5, and perennial ryegrass by x 3, while yields of Agrostis stolonifera were reduced to 40% and Poa trivialis to 20% of those on the unsprayed control plots. Yields of dicotyledonous weeds were reduced by 50% while the other component consisting of miscellaneous grasses had increased by 1.7. Total dry matter yields of the treated plots exceeded those of the controls by 150%. Using lower rates of paraquat in May 1962, Jones, L. and David (1962) studied the reaction to paraquat of pure stands of S.24 ryegrass, S.37 cocksfoot, S.170 tall fescue, S.48 timothy and S.22 Italian ryegrass

in May, July and September at 0.5, 1.0 and 2.0 lb/ac, to a hill sward containing Molinia caerulea, Nardus stricta and Festuca spp. together with Juncus spp. and Vaccinium myrtalis. The grasses formed some 80% of the original population, but by the end of 1960 this had been reduced to 4% in the sprayed plots; and even at the end of the second year, regrowth and recolonisation had increased the population to only 19% of that on the untreated sward. Nardus stricta was very susceptible to paraquat and was rapidly eliminated by all treatments. Molinia caerulea responded more slowly, but was eventually killed. Festuca spp. were initially suppressed by May and July applications but recovered to nearly their original level by the peak growth period in the second year. Treatment in September severely reduced Festuca spp.

British experience with paraquat may be summarised as follows:-

1. Paraquat shows selective toxicity between the grasses and this can be modified by the inclusion of a wetting agent. There is evidence of a marked selectivity between perennial ryegrass and Poa trivialis. The order of species susceptible to paraquat appears to be:-

most resistant: Cocksfoot, ryegrass (perennial strains)
Festuca rubra, F. tenuifolia
Holcus lanatus
Phleum pratense
F. pratensis
Agrostis stolonifera

least resistant: Poa trivialis, P. annua, Nardus stricta
Molinia caerulea, Italian ryegrass

2. Because the tolerance of species changes with season the time of application is important.

3. White clover, although scorched initially by paraquat, recovers rapidly and can increase in mature grass swards.

Paraquat. New Zealand.

Compared with Great Britain, considerably less work has been done in New Zealand on the selective effects of paraquat on grasses. Bramley (1961) investigated the tolerance of pure stands of 3-year-old Lolium perenne, Dactylis glomerata, Agrostis tenuis, Festuca rubra var. fallax and Holcus lanatus to 0.45, 0.9 and 1.8 lb/ac of paraquat applied in late December 1960 and late March 1961. Applied in December or March, paraquat at 0.45 lb/ac had a negligible effect on perennial ryegrass, but the 0.9 and 1.8 lb/ac rates produced increasingly severe effects as indicated by assessments made 3 months after spraying. Cocksfoot was more susceptible to 0.45 lb/ac paraquat applied in either December or March than was ryegrass; against cocksfoot, March applications had more severe effects than December. At either date, a rate of 1.8 lb/ac almost eliminated cocksfoot and 0.9 lb/ac gave 75% control. Agrostis tenuis was markedly more tolerant of paraquat applied in March than in December, the high rate in March giving no better control than the low rate in December. Paraquat at 0.45 lb/ac, 3 months after application in December, gave 40%, 0.9 lb/ac

80% and 1.8 lb/ac about 90% reduction of Agrostis, while 1.8 lb/ac was required for a 40% reduction 3 months after the March application. About 50% reduction of Festuca rubra was achieved with 0.45 lb/ac paraquat applied in December, while 0.9 and 1.8 lb/ac gave 85 and 95% control, respectively. These rates applied in March were less effective, 0.9 lb/ac being required for about 60% reduction and 1.8 lb/ac for an 80% reduction. Holcus lanatus was reduced 95% by as little as 0.45 lb/ac applied in March, but this rate applied in December allowed 44% survival and only the high rate achieved kills comparable with the March applications. Poa trivialis which was a contaminant of the ryegrass plots was eliminated by all rates of paraquat applied in December and by 1.8 lb/ac applied in March. In March 0.45 lb/ac caused about 50% reduction.

Bramley (1961) showed that young plants of lucerne, red, white and subterranean clovers sown in early November and sprayed 5, 7, and 9 weeks after sowing in a dry season showed marked susceptibility to paraquat at rates of 0.2 to 3.6 lb/ac. Most plants of white, red or subterranean clover were eliminated by rates of about 0.9 lb/ac. More mature plants showed increased tolerance. Paraquat at 0.45, 0.9 and 1.8 lb/ac was applied in late December or in late March to established white clover in a 2-year-old sward. At both times of application the clovers were quickly defoliated but recovery of the surviving plants was rapid and control levels exceeded by all treatments except 1.8 lb/ac applied in March. Assessments were carried out 3 months after each application.

Leonard (1964) applied paraquat in March, April, May and October to a ryegrass/white clover sward infested with barley grass (Hordeum murinum). March, April and May applications produced similar results and 2 oz/ac paraquat plus wetter produced a 40% and 3 - 4 oz/ac a 70% reduction of ryegrass compared with untreated control, while 3 oz/ac in October gave more than 85% reduction. White clover showed big increases - up to twice control level - following the October applications of paraquat. Much of the experience on the use of paraquat in New Zealand and Great Britain has led to similar conclusions. A summary of New Zealand work indicates:-

1. That paraquat shows selective toxicity between grasses, and omitting several species not studied by the New Zealanders, the order of species' tolerance is similar to that found in the United Kingdom.

2. Species' tolerance changes with season. Time of application is therefore important.

3. Though more susceptible when young, white clover is relatively resistant to paraquat and can increase markedly in mature swards under conditions of reduced competition from grass.

PART II - SOME FACTORS INFLUENCING SELECTIVITY

The Chemicals

The selective herbicide is described (Klingman 1961) as a chemical that is more toxic to one plant than another. This description requires amplification in the context of grassland, and with reference to the three main phases of chemical activity (Elliott 1960) which are:-

1. The period of direct action following application.
2. A static period due to residual activity in soil or plant.
3. The regrowth to a new sward equilibrium.

A chemical may be selective because it is more toxic in the first phase to one species than to another. This is the simplest form of selectivity. Ideally the chemical should be lethal to its intended victims and without effect on the other plants, but in practice this contrast is rarely achieved, it is usually a matter of one species reacting more than another, or of one species reacting for longer than another. In either case the speed of chemical action, and therefore the duration of phase one, is important. A chemical with a fast action may not allow the resistant species a time advantage in entering the regenerative phase. One with a slow action may allow the resistant species to regrow in phase three while the susceptible species is still held in stage one or two. The slow acting chemical would appear preferable.

A chemical may be capable of producing selective changes in pasture although, in phases one and two, it has an equal and sub-lethal effect on all species in the sward. The ability of a species to make rapid or extensive regrowth could ensure a dominance over other less agressive constituents of the sward. It is more likely to do this when the chemical application coincides with the beginning of the period of its maximum growth. If the sward constituents differ in the timing of their growth periods, dominance of the sward could be varied by altering the time of chemical application. This technique would be similar in effect to the variation of sward composition by grazing at different seasonal times. (Martin Jones 1937).

A chemical may be capable of producing selective changes without killing. In this property the herbicide as used in grassland differs from that used in arable husbandry. Since the plants growing in a sward are in a state of competitive equilibrium, the application of a chemical that inhibits the growth of some but not all, may be sufficient to tip the balance against the susceptible plants. Though obviously, much would depend on the ability of the resistant plants to benefit from the opportunity that is offered.

The two chemicals that have been used most in experiments are dalapon and paraquat; they provide a marked contrast in performance. When used at doses of 5 lb/ac or less, dalapon produces little immediate scorch or other visible symptoms. About 4 - 6 weeks pass while the chemical develops its systemic action, and phase one can be considered over. Dalapon has an appreciable persistence in the soil, but how long this lasts under a grass sward is not known. After dalapon is applied all grasses suffer some restriction in growth, but as time elapses after spraying, the more resistant species regrow while the foliage of the susceptible ones continues to die. Paraquat is quite different in its action; scorch effects on all species are apparent within 24 hours of application and the full effect on foliage is reached in 7 - 10 days; translocation to the roots takes a little longer. Phase two can hardly be said to exist for paraquat because it is rapidly absorbed and inactivated on contact with most soils. Thus the beginning of phase three is reached by all species soon after spraying, the foliage of the sward is uniformly dead, and regrowth starts from unharmed tiller buds and surviving root systems.

The contrast in performance by these two chemicals is very striking and it is therefore appropriate to consider which type of action is likely to fit in with the circumstances of the grass sward. It is suggested that the slow systemic type of action is the one likely to be most successful. A gradual decline in the vegetative production of the susceptible plants being matched by a steady increase in that of the resistant. Indeed it might be that soil acting chemicals have a part to play. A slow action on perennials and persistence in the soil are properties that could well be used, providing the correct selective toxicities were available.

Biological Factors.

The aim of selective change is the suppression or elimination of the undesirable and the encouragement of the desirable species so that the spaces left vacant are colonised by the latter. The nature of the spaces, their size and distribution, and the nature of the plants that fill them are all vitally important to the success of the operation.

One of the facts of pasture agronomy, and an unfortunate one so far as recolonisation is concerned, is that grass species differ in habit of growth. Most of the so-called desirable grasses are tufted in growth, they are therefore relatively immobile and can only spread vegetatively by means of tiller production on the periphery of the area already inhabited. Since tiller primordia are only laid down at certain times of the year, the ability of the plants to extend may also be restricted by season. In contrast, a number of the undesirable grasses, notably Agrostis and Poa spp., are stoloniferous or rhizomatous in habit, and are capable of ramifying extensively over vacant ground so as to provide a herbage cover in a comparatively short time. Shoots and roots can arise from nodes still connected to the parent plant which may be some distance away, and this provides them with an agressive ability to extend their area of dominion from a low initial presence. The nature of these properties suggests an important role for white clover in the process of re-colonisation. Being stoloniferous in habit, it is capable of invading vacant spaces quickly providing this is timed to fit in with its growing season. It might be that selective change could be achieved in two stages, an initial colonisation by white clover could be followed by a treatment with nitrogen to encourage grass at the expense of the clover, if an unduly high proportion were present.

Though the surface vegetation is important, it is only part of the soil/plant complex that goes to make up grassland. Another part relevant to selectivity is the population of dormant seed and root systems in the soil. It can be assumed that the soil underlying every grass sward will contain many millions of seeds per acre. Since these seeds are derived from the vegetation growing on the surface, every species in the sward will be represented, together with others, that were present in years gone by. It requires only the removal of the foliar canopy to provide the stimulus for a proportion of these seeds to germinate and colonise the vacant space. Similarly, it is known that the removal of the vegetative cover can activate dormant root systems, though not a great deal is known about the circumstances where this may occur. The extent of its importance in selectivity may need to be the subject of future experimentation.

In essence the success of a selective herbicide hinges on how the species compete for possession of the vacant spaces. Leaving aside for the moment, invasion by seedlings which may in any case be controlled by a soil-acting herbicide, the smaller the space the more easily and quickly will it be colonised by tufted grasses along its boundaries accepting that adjoining stoloniferous species will have a marked advantage. In general the smaller the porportion in area of space to colonisers, the easier is the encroachment, but as the proportion of space increases, it becomes more difficult for tufted species to achieve the quick colonisation that is necessary. From this there arises the concept of a threshold presence of colonisers, above which the spaces can be filled in reasonable time and below which they cannot. Put in agricultural terms, above the threshold, sward improvement could be achieved by a selective herbicide, below it some form of reseeding would be necessary.

The threshold is bound to vary with circumstances. Where there is an even distribution and mixture of desirable and undesirable species, colonisation could be achieved by a relatively lower presence of desirables than if the two groups were zoned in their distribution; because in the first circumstance a selective herbicide would create large numbers of small spaces adjoined by colonisers, while in the second the spaces would be larger and therefore more difficult to colonise. The sward content of desirables and their distribution are therefore both important. An ability to judge the threshold presence is necessary to ensure the success or failure of the outcome. It need only be added that almost nothing is known about threshold values.

Agronomic Aspects of Selectivity.

The object of developing selective herbicides for use on grassland is to increase sward productivity. To do this, a selective change in botanical composition must in the end result in an association of species that is more productive than that originally present. Herbicides are only indirectly able to do this. The nature of chemical action is to be depressive to growth, and a selective chemical is more depressive to some species than others. It follows therefore that the temporary reduction in total herbage production brought about by a selective herbicide must be reversed quickly. This can be achieved by the use of fertilisers, in association with the herbicide, to stimulate the survivors and restore production. The association of nutrient action with a selective herbicide is important for another reason. The species composition of a sward is a product of the environment to which it has been subjected, and the nutrient status of the soil is an important part of the environment. An improvement in botanical composition requires an immediate improvement in the environment, of which the nutrient status is the one factor that can be changed quickly. There are, of course, other aspects of the environment that may need correction, as for example, drainage or grazing management, but the changes wrought by these occur relatively slowly.

Selective chemicals to control the composition of grass swards could find many uses on the different pastures of the British Isles. The control of grass weeds in young or established leys is an outstanding requirement (Baker 1960). This use could be likened to selective control in the arable sense; the crop has been sown at some expense and it is required to produce its maximum of herbage in order to repay its costs. In this situation the selective chemical must be capable of suppressing the weed without adverse affect on the crop. Sown evenly over the ground and composed of vigorous plants, the ley in its early years resembles an arable crop in its ability to take up the space relinquished by the weed as it succumbs to the chemical. With increasing age a ley becomes less like an arable crop and more like a permanent pasture in its performance and therefore in its herbicidal requirements.

On old pastures the situation has no similarity to arable weed control, and a more ecological approach is appropriate. Where some extreme of environment is the cause of a particular sward composition, there is usually no alternative to correction if an improvement in production is desired. There are many millions of acres of permanent pasture in the United Kingdom which do not suffer extremes of environment, and on which selective improvement could be achieved in association with quite small managerial changes in fertiliser and animal use. On such swards, the use of herbicides to achieve botanical change may involve some temporary loss of herbage production as the vacant spaces are filled, but this loss should not be as great as that resulting from ploughing and reseeding. Indeed the use of a herbicide in this way can be seen as lying mid-way between reseeding on the one hand and improvement by grazing and fertilisers on the other.

The broad trend of experience encountered by research workers in both New Zealand and the United Kingdom has been that selective changes in swards can be achieved by the use of herbicides. For example, well established perennial ryegrass has more resistance to dalapon than have Agrostis spp. and Poa spp., to name but two, and the use of dalapon on a mixed sward containing these species has lead to an increase in the content of perennial ryegrass. Much work remains to be done to clarify the circumstances under which herbicides can induce the desired changes, and to measure the resultant effects on sward output. Until such details are known, the significance of the technique for British Agriculture cannot be assessed.

References

ALLEN, G.P. (1964) in press

BAKER, H.K. (1962) A survey of English Grasslands. Proc. 6th Brit. Weed Control Conf. 1, 23-30.

BRAMLEY, P. (1961) New developments in the weedkiller field. Proc. 14th New Zealand Weed Control Conf. 41-47.

CHARLES, A.H. & LEWIS, J. (1962) Observations on the use of herbicides on grassland. Proc. 6th Brit. Weed Control Conf. 1, 75-83.

DAVIES, G.E., HUNTER, R.F. & KING, J. (1960) Hill pasture improvement with dalapon. Proc. 5th Brit. Weed Control Conf. 157-164.

DOUGLAS, G. & MCILVENNY, H. (1962) The use of paraquat as a sward-killer in the improvement of hill communities and lowland pastures. Proc. 6th Brit. Weed Control Conf. 1, 45-55.

ELLIOTT, J.G. (1960) The evaluation of herbicidal activity on a mixed sward. Proc. 8th Int. Grass Congress. 261-271.

FRYER, J.D. (1962) Private communication.

FRYER, J.D. & CHANCELLOR, R.J. (1958) The toxicity of dalapon and amino-triazole to some common British grasses - a progress report. Proc. 4th Brit. Weed Control Conf. 197-203.
GARDNER, A.L. (1960) The use of dalapon for grassland improvement in the south-west of Scotland. Proc. 5th Brit. Weed Control Conf. 1, 171-177.
HOLROYD, J. (1964) Private communication.
HOLROYD, J. (1964) Private communication.
JONES, J. (1962) Dalapon as an aid to sward renovation. Proc. 6th Brit. Weed Control Conf. 1, 65-73.
JONES, L. (1962) Herbicides to aid pasture renovation. J. Brit. Grassl. Soc. 17, 85-86.
JONES, L. & DAVID, G.L. (1963) Expts. in Prog. 16, Ann. Rep. 1962/63 of the Grassl. Res. Inst., Hurley, England.
JONES, M. (1937) The improvement of grassland by its proper management. Proc. 4th International Grassl. Congress, 470-473.
KLINGMAN, G.C. (1961) Weed control as a science, Wiley.
LAWSON, H.M. (1962) Dalapon for hill land improvement without reseeding. Proc. 6th Brit. Weed Control Conf. 1, 57-64.
LEONARD, W.F. (1964) Barley grass control. Proc. 16th N.Z. Weed Control Conf.
MATTHEWS, L.J. (1960) Chemical ploughing in New Zealand. Span. 3, (4), 160-163.
THOMPSON, A. (1958) Tolerance of pasture species to dalapon and amitrol. Proc. 11th N.Z. Weed Control Conf. 96-103.
THOMPSON, A. (1959) The effect of dalapon on various grass species. Proc. 12th N.Z. Weed Control Conf. 24-29.

PERMANENT GRASSLAND IN THE FEDERAL REPUBLIC OF GERMANY

- PRESENT STATUS AND POSSIBLE IMPROVEMENTS -

G. Ziegenbein

Staatliche Lehr- und Versuchsanstalt für Grünlandwirtschaft und Futterbau, Eichhof, Bad Hersfeld, Germany.

Summary: The present paper reports on the extent and special characteristics of grassland in the Federal Republic of Germany, on problems of grassland research and on the practical application of research results. The part played already by herbicides in the grassland system is shown and the possible developments on this field are discussed.

Approximately 40 % of the agricultural acreage in the Federal Republic of Germany are meadows and pastures. Depending on climatic and soil conditions the various regions of the country have greatly differing proportions of grassland. The north German coastal area, the mountains and their borderlands and the river valleys are rich in permanent grassland. The plains protected from rain by mountain ranges and the areas of viniculture have only a slight proportion of grassland. 35 % of the 5.7 million hectares of permanent grassland in the Federal Republic are called "pastures" in the official statistics, i.e., they are used predominantly for grazing, and the remaining 65 % are so-called meadows, where forage is obtained mainly in the form of hay. In addition, forage plants are cultivated on about 1 million hectares of arable land, including grass-clover leys (Table 1).

Table 1

Forage production in the Federal Republic of Germany expressed in 1000 h

Year	Meadows	Pastures	Forage plants on arable land
1935/38	3624	1909	1223
1950	3646	1928	1239
1955	3617	1986	1087
1956	3627	2016	1017
1957	3622	2018	1016
1958	3616	2025	995
1959	3653	2039	989
1960	3652	2053	954
1961	3629	2076	980
1962	3615	2102	933
1963	3604	2114	937

In Germany we have almost exclusively so-called "absolute grassland". This means that ecological or economical conditions in these areas preclude utilization as arable land. The reasons for using these areas as permanent grassland are:

1.) high ground-water levels or danger of inundation in the extensive river flats,
2.) very heavy soils,
3.) shallow and stony soils in mountainous areas,
4.) mountain slopes which are difficult to plough and which involve the risk of erosion,
5.) peat land with heavy weed growth and exposure to frost, and which readily lose their structure after having been cultivated,
6.) mountain regions with heavy precipitation and a brief vegetation period,
7.) Economic aspects also play a part in some cases, such as unfavourable transport conditions.

Rotation leys are very rare in Germany. They are found in some cases under extensive mountain conditions or in Schleswig Holstein.

According to the official statistics the average yield of our grassland is about 6000 kg/h of hay and 1600 kg/h of starch equivalents. The proportion of high-grade grassland is slowly growing.
For about 30 years scientists and research workers have dealt intensively with problems of pasture improvement. The results of these efforts are now becoming apparent in practice and have contributed to the increase in livestock and milk production.

Table 2

Livestock and milk supply in the Federal Republic of Germany

Year	Cattle millions	Cows millions	Year	Milk Supply million t
1948	10.5	5.2	1948	8.6
1949	11.-	5.3	1949	11.3
1950	11.3	5.6	1950	13.9
1957-62	12.7	5.8	1956-61	13.2
1963	13.-	5.9	1962	15.5

These efforts are based on the results of many years of trials to improve the yield of grassland. This development is not nearly complete, it is expanded and refined by research , and extension officers are making every effort to appeal to a larger number of farmers.

The first measure of grassland improvement is in many cases the control of the water conditions. The straightening of river beds, construction of high-water dams or reservoirs affect the agriculture of entire districts and need intensive advisory service for the farmers. Moreover the draining of too wet areas has resulted in better water conditions, so that grassland which previously has been extensively used as meadows has become profitable pasture grounds.

Systematic maps on the plant sociology of the permanent grassland of larger areas provide important data for the planning of these improvement measures and for later individual advice concerning a more intensive utilization of the grassland. Our seminatural grassland contains a relatively large number of plant species. Different environmental and management conditions have developed various plant communities composed of grasses, clovers and herbs. These communities are in a dynamic equilibrium with their environment and show usually a high flexibility in the proportions of plants in different years and in the number of species dependent on fertilization and management procedures applied. So, the most important approach to grassland improvement is to use this flexibility for the development of desirable and productive grass swards.

The following measures are taken to change the species composition of the grassland plant:

1.) Regular use of mineral fertilizers or increase in the amount of fertilizer. The growing consumption of commercial fertilizers per hectare agricultural land (table 3) also applies to grassland and will probably continue to rise. With the aid of a satifactory supply of nutrients the poor-yielding components of the plant community will gradually be replaced by those species capable of utilizing high amounts of nutrient. Unbalanced fertilizer treatment however, may also promote the growth of undesirable species, such as umbelliferae.

Table 3

Use of mineral fertilizers (pure nutrients in kg/ha) in the Federal Republic of Germany

Year	N	P_2O_5	K_2O
1946/47	13.1	9.2	2o.9
1947/48	18.4	15.1	28.5
1948/49	23.3	28.5	4o.1
1949/5o	23.1	24.2	41.6
195o/51	25.6	29.6	46.7
1952/53	29.5	27.7	54.3
1953/54	31.-	32.1	58.5
1954/55	31.7	36.3	6o.2
1955/56	33.1	33.6	59.4
1956/57	36.9	4o.1	61.5
1957/58	39.7	41.6	69.2
1958/59	4o.2	44.3	7o.1
1959/6o	43.6	5o.9	73.-
196o/61	43.4	46.4	7o.6
1961/62	43.7	44.6	72.9
1962/63	54.1	5o.7	77.5

2.) For this reason and in order to make increased expenses for fertilizers more economical, a change in the management systems is absolutely necessary. Wherever the conditions of the farm and grassland sites permit, meadows are converted into pastures. Rough grazings and continously grazed pastures are sub-divided into paddocks and used in a rotational or strip grazing system. For highest production and the control of pasture weeds, each paddock should be mown once a year for hay or silage. This form of utilization combined with high fertilization improves the yields and the sward, the first by utilizing the forage in a favourable mutritive stage and the latter by avoiding over- and underuse. At the same time the forage of the mown paddocks provide hay and silage as conserved fodder.

3.) Thus the improvement of grassland production includes the development of the fodder conservation in the form of silage and barn drying. Government subsidies are available for building barns etc.

4.) Relatively high expenditure in the forage plant production are justified only with high-grade cattle. The condition of the latter was improved among others by goverment-subsidised measures to control diseases. German cattle are virtually free from tuberculosis and 80 % from brucellosis. The number of cows under performance control is steadily increasing, although at present only about 36 % of all cows are registered.

5.) The utilization of the existing grassland in the form of intensive pastures is more feasible in areas with isolated farms than in areas where the farms are placed together within village communities, and are usually subdivided by inheritance. In these cases the plots of one farm are distributed all over the area and are relatively small and often far distant from the farmstead. The government supports the consolidation within a community. This measure in many cases requires that entire farms are evacuated from the village grounds. Once the new farmstead is situated in the centre of the farmfields, the grassland may be managed by modern methods. This action is in full swing, and between 1945 and 1962 has involved 2.8 millions hectares.

In addition to the above large-scale and fundamental methods for grassland improvement there are a number of other possibilites to improve grassland utilisation and increase the reliability of its results.

1.) There are still isolated areas in relatively dry regions which should be ploughed up and put to arable use. In mountain rejons where the inhabitants already have partly emigrated or found employment in industry as "commuters", poor grassland soils are to be afforested.

2.) On the other hand in areas with a high amount of precipitation efforts are being made, and have in some cases already been realized, to convert farms into pure grassland farms instead of using part of the fields as arable land. This specialization results in better farm profits, because the expenses for fertilizers, machines and buildings are all directed towards grassland management and because the knowledge and experience of the farm manager and his staff may be concentrated exclusively on grassland farming.

3.) In former times, it was believed, that improvement of the grassland sward following water regulation, might be accelerated by ploughing up and reseeding with valuable grasses and clovers. The various experts held controversial opinions on the techniques of ploughing and whether the ground should be used as arable land for one or several years between ploughing and reseeding. The longer period was argued to result in better control of typical undesirable grassland weeds. Progress has superseded this difference in opinion. In several instances ploughing failed, because the new seeds had difficulty in establishing after ploughing of these soils, especially if the humus content of the old grass sward had been largely destroyed by intermediate arable farming. In other cases ploughing up and reseeding gave useful results, especially where the newly sown areas received good management. However this procedure involves considerable risk. For this reason the experts decided that the undesirable plant community of a grassland sward might almost always be safely improved by judicious management measures. This conversion, of course, takes several years. Attempts have also been made to sow good grasses into gaps in the swards. The results have been very variable. This method therefore is considered unreliable.

4.) Increased fertilization and utilization by repeated mowing or intensive grazing necessarily result in a diminution of the species concerned in the sward. In this manner poor components and part of the weeds will gradually disappear. This procedure has recently been accelerated, especially in the cases of toxic weeds, by the use of herbicides. But our pasture experts are rather reserved in employing this procedure and restrict it to individual cases because they are afraid that the routine use of herbicides in pasture lands may interfere with the favourable spectrum of species, to wit, that in addition to the weeds also desirable herbs and legumes might be decreased or destroyed, thus reducing the nutritive value of the green-forage.

Since the majority of dicotyledonous weeds occur in clumps in pastures, and are not distributed evenly over the entire area, grassland and herbicide specialists have agreed not to apply herbicides in grassland in the form of surface spraying, but to use them selectively against clusters of weeds.

In addition, efforts are being made to use agents which spare the clovers. If nevertheless an entire area has to be sprayed in isolated cases because the weeds to be controlled are distributed evenly all over it is recommended to use a lower rate of herbicide and, if necessary, to repeat the spraying next year as an individual control measure. Where clovers are present in larger quantities phenoxybutric herbicides are preferable.

The farmers are advised that herbicides alone should never be considered as a panacea, but that their use should be associated with improved management, so that the remaining desirable species may rapidly fill in the gaps left by the destroyed undesirable species.

5.) The pasture improvement methods employed in Great Britain by chemical ploughing up with subsequent reseeding has not yet been widely accepted in this country, but has already been used successfully in trials. The author has been working with dalapon and paraquat. One of the advantages of paraquat is that the fields may be sown a few days after treatment. When performing this treatment in August only one harvest in the form of a grass cutting or of grazing is lost. Next spring the sward may be fully utilized. Because of the persistance of dalapon at least 2 harvests are lost. In addition, broad-leaved weeds recover especially in areas, where the competition of grasses has been largely eliminated by dalapon. The rapid and dense growth of clover and grass following the use of paraquat largely prevents the invasion of broad-leaved weeds. Paraquat, however, does not destroy all grasses equally, so for instance the rhizomes of Agropyron repens will survive. The author's observations on the behaviour of other weed grasses treated with paraquat are limited. In the author's opinion the destruction of undesirable pasture swards in Germany with the aid of herbicides and reseeding without ploughing may come to play an important part in the further intensification of our pasture lands.

The grassland improvement in Germany with the aid of chemicals as culture tool appears useful under the following conditions:

1.) Conversion of mountain grassland into rotation pastures. Fertilization and management will produce only a very gradual change in these swards which consist predominantly of poor types in these areas with a relatively short vegetation period so that the increased fertilization is not fully utilized during the first years. These areas are in regions with a high amount of precipitation and often on shallow, stony soils offering great difficulty for ploughing operations.

2.) Mechanical ploughing up is impossible where the grassland sward is to be rapidly improved in inundation areas or in areas with a high groundwater level, The destruction of the sward by chemicals followed by re-seeding with only superficial cultivation is a much more practical approach to this problem.

3.) On peat land and on very heavy mineral soils ploughing up may cause desiccation and destruction of soil structure. Rapid reseeding after killing the plants leaves the area uncovered for only a very brief period.

4.) In addition to these special cases the creation of a high-yielding plant community by chemical destruction of the low-yielding sward and sowing of more productive species should be considered, wherever rapid improvement of the grassland sward is desired to make pay the investments for more intensive pasture utilization, such as nutrient supply, fences and hig-grade cattle.

REFERENCES

1 ARENS, R. (1958)	Umbruchlose Verbesserung von Rotschwingelweiden, Zr.Acker- u.Pfl.Bau 107, 195
2 BADEN, JANNER, BOEKER (1957)	Beiträge zu Fragen der Grünlandbewirtschaftung, AID, Landwirtschaft-Angewandte Wissenschaft Nr. 67
3 BOEKER, P. (1955)	Narbenverbesserung durch intensive Weidenutzung, Grünland 4, 58
4 BUNDESMINISTERIUM FÜR ERNÄHRUNG, LANDWIRTSCHAFT UND FORSTEN (1959)	Spiegel der westdeutschen Landwirtschaft Münster
5 BUNDESMINISTERIUM FÜR ERNÄHRUNG, LANDWIRTSCHAFT UND FORSTEN (1963, 1964)	Grüner Bericht und Grüner Plan München und Bonn
6 DAIBER, C. (1957)	Untersuchungen zur Stadienempfindlichkeit verschiedener Wiesenkräuter und -leguminosen gegen herbizide Wuchsstoffe, Zr. Acker- u.Pfl.Bau, 102, 410
7 HANF, M. (1953)	Der Einfluss der Unkrautbekämpfung mit Wuchsstoff auf den Pflanzenbestand des Grünlandes, Zr. Pfl.Bau u.Pfl.Schutz 4, 1
8 HOLZ, W., RICHTER, W. (1958)	Versuche auf ganzflächig mit Wuchsstoffherbiziden behandeltem Dauergrünland, Zr. Pfl.Krankheiten und Pfl.Schutz 65, 199
9 HOLZ, W. (1963)	Neuere Ergebnisse bei der Duwok-Bekämpfung mit dem Kortlang'schen Untergrundschneider, Vortrag Hohenheim
10 KLAPP, E. (1938)	Bearbeitungs-, Nachsaat-, Umbruchs- und Düngungsversuche auf Grünland, Pfl.Bau 14, 241
11 KLAPP, E. (1953)	Wiesen und Weiden, Hdb. Landwirtschaft Berlin und Hamburg
12 KLAPP, E. (1954)	Wiesen und Weiden Berlin und Hamburg
13 KÖNIG, F., MOTT, N. (1959)	Neuansaat, umbruchlose Verbesserung, Nachsaat, Zr.Acker- u.Pfl.Bau 108, 177
14 MÜLLER, [illegible]., ORT, H. (1963/64)	Vergleichende Untersuchungen zur Bekämpfung von Allium vineale im Grünland, Zr. Acker- u.Pfl. Bau 118, 275

15 RADEMACHER, B. (1953) Das Verhalten der wichtigsten Grünlandpflanzen gegen herbizide Stoffe, Zr. Acker- u. Pfl.Bau 97, 1

16 RADEMACHER, B. (1958) Zusätzliche Bekämpfung der Grünlandunkräuter mit chemischen Mitteln, Mitt. DLG, 73, 532

17 RICHTER, W., HOLZ, W. (1960) Wuchsstoffe zur Unkrautbekämpfung im Grünland und ihre Wirkung auf den Pflanzenbestand, Zr. Acker- u. Pfl.Bau, 110, 289

18 RICHTER, W. (1963) Versuche zur Bekämpfung des Wasserkreuzkrautes (Senecio aquaticus Huds.) auf nordwestdeutschen Weiden, Zr. Acker- u.Pfl.Bau 116, 2o5

19 STÄHLIN, A. (1957) Kraut und Unkraut im Dauergrünland der Mittelgebirge, Grünland, 6, 73

20 STÄHLIN, A. (1959) Die Entwicklung von Weideansaaten unter dem Einfluss von Standortsfaktoren, Düngung und Bewirtschaftung, Zr. Acker- u.Pfl.Bau 109, 127

21 STATISTISCHES JAHRBUCH für die Bundesrepublik Deutschland 1963, Stuttgart und Köln

22 WEISE, F. (1958) Die Pflanzengesellschaften der Dauerweiden des Flachlandes, ihre Kennzeichen und ihre Bewirtschaftung, Kali-Briefe

23 WEISE, F. (1961) Grünlandintensivierung im Spiegel des Pflanzenbestandes, Zr. Acker- u. Pfl. Bau 114, 53

Research Summary

THE CONTROL OF BRACKEN FERN WITH 4-AMINO-3,5,6-TRICHLOROPICOLINIC ACID.

H. M. Lawson
Dow Chemical Company (UK) Limited, Kings Lynn, Norfolk.

Summary. Experiments with 4-amino-3,5,6-trichloropicolinic acid applied as a pre- or post-emergence spray treatment, have given excellent control of bracken (*Pteridium aquilinum*), for two full seasons after application.

INTRODUCTION

The series of trials reported in this paper was laid down in the United Kingdom in an attempt to study the performance of 4-amino-3,5,6-trichloropicolinic acid under a variety of environmental conditions. One trial was sited in the dry Breckland area of East Anglia, another in a mild, wet area, in south-west Scotland, and a third on an exposed hillside at 1,500 ft. above sea level in mid-Wales.

4-amino-3,5,6-trichloropicolinic acid, as TORDON* 1665 herbicide, was applied in a salt formulation at 3/8, $\frac{3}{4}$, $1\frac{1}{2}$, 3 and 6 lb. a.e./ac. at different stages of growth during the summer, and a further treatment was applied pre-emergence the following spring. Plot size was 6^x x 4^x with a 4^x discard between plots. The treatments were not replicated at each site, but the trial layouts were similarly designed at the three locations.

The Breckland site was very dense and uniform and the bracken had a thick layer of trash under it. Bracken on the other two sites was more 'clumpy' on a thick turf sod. Application was made with an Oxford Precision Sprayer in a volume of 30 gals. water/ac.

The first post-emergence treatments were applied while the fronds were still emerging and had not unfurled. The second post-emergence application was just before full frond expansion. The pre-emergence treatments were applied to bracken trash or to turf the following spring, some 2 - 3 weeks before the first fronds broke through the ground.

SYNOPSIS OF RESULTS

Frond counts were made one and two full seasons after treatment. All emerged fronds were counted regardless of condition. A yard wide discard was left round each plot to allow for encroachment. Results from all three sites are included to give an indication of site variance at various dosage rates.

* Registered Trademark of The Dow Chemical Company.

Table I.

September 1963 Assessment Percentage bracken frond reduction relative to untreated control						
Stage of growth at treatment	Date of application	Treatment (4-amino-3, 5, 6-trichloropicolinic acid lb a. e./ac.) 6	3	$1\frac{1}{2}$	$\frac{3}{4}$	3/8
Early frond emergence						
Expt. G1 - Norfolk	27. 6. 62.	99	74	66	34	27
Expt. G2 - Radnor	4. 7. 62.	97	82	70	-	68
Expt. G3 - Kirkcud-bright	11. 7. 62.	99	98	80	-	28
	Mean	98	85	72	34	41
Full frond emergence						
Expt. G1 - Norfolk	23. 7. 62.	95	60	39	23	5
Expt. G2 - Radnor	8. 8. 62.	91	80	69	-	62
Expt. G3 - Kirkcud-bright	16. 8. 62.	93	68	31	-	7
	Mean	93	69	46	23	25
Pre-emergence						
Expt. G1 - Norfolk	8. 4. 63.	99	98	92	81	47
Expt. G2 - Radnor	10. 4. 63.	100	99	98	92	89
Expt. G3 - Kirkcud-bright	18. 4. 63.	100	95	93	48	66
	Mean	100	97	94	74	67

Table II.

September 1964 Assessment a) Percentage bracken frond reduction relative to untreated control b) Percentage ground cover of bracken											
Stage of growth at treatment	Date of application	Treatment (4-amino-3,5,6-trichloropicolinic acid lb a.e./ac.) 6		3		$1\frac{1}{2}$		$\frac{3}{4}$		3/8	
Early frond emergence		a	b	a	b	a	b	a	b	a	b
Expt. G1 - Norfolk	27.6.62	98	1	69	20	76	15	50	55	63	70
Expt. G2 - Radnor	4.7.62	99	2	83	15	58	40	-	-	36	50
Expt. G3 - Kirkcudbright	11.7.62	100	0	100	0	83	10	-	-	62	50
	Mean	99	1	84	12	72	22	50	55	54	57
Full frond emergence											
Expt. G1 - Norfolk	23.7.62	89	2	66	30	+2	90	3	95	+16	98
Expt. G2 - Radnor	8.8.62	90	5	58	30	46	45	-	-	23	55
Expt. G3 - Kirkcudbright	16.8.62	91	10	50	20	18	70	-	-	0	80
	Mean	90	6	58	27	21	68	3	95	2	78
Pre-emergence											
Expt. G1 - Norfolk	8.4.63	94	1	93	1	69	10	38	50	+6	80
Expt. G2 - Radnor	10.4.63	98	3	93	5	68	40	54	55	51	60
Expt. G3 - Kirkcudbright	18.4.63	94	5	62	10	23	20	+35	40	+54	70
	Mean	95	3	83	5	53	23	19	48	+3	70

Percentage ground cover data were taken because of the clumpy nature of regrowth on many plots.

DISCUSSION

Early post-emergence spray treatment gave rise to severe frond distortion and malformation. These symptoms were not nearly so marked on the more mature fronds sprayed at the later date. With the pre-emergence treatments, frond stems broke surface and died back rapidly all through that growing season.

Frond assessments show clearly that early post-emergence treatment has been consistently superior to treatment at full frond emergence. Although results are not completely comparable, the pre-emergence treatments appear to be as effective as early post-emergence treatments.

6 lb. a.e./ac. gave virtually complete control of bracken over two full seasons at all sites and all treatment dates. Excluding the full frond emergence treatments, it appears that a single treatment in the range $1\frac{1}{2}$ - 3 lb. a.e./ac. especially if coupled with sound reclamation management, may give a commercially acceptable level of control.

Further trials are under way to confirm the optimum stage of growth and to find the effect of split treatment application, combinations of spraying and cutting and to evaluate granular formulations. The germination and establishment of seeded white clover on sprayed sites is being assessed. Results so far look promising.

No treatment rate has harmed turf grasses at any date of application, although all broadleaved weeds in association with the bracken have disappeared.

Most herbicides appear to work best on bracken when sprayed at full frond expansion. The physical difficulty of so treating dense, tall bracken has made cost of application prohibitive. Pre-emergence or very early post-emergence treatment of bracken, therefore, offers many advantages in terms of actual application of the herbicide. The promising results obtained with 4-amino-3,5,6-trichloropicolinic acid in these trials open up new possibilities for the development of economic application techniques.

Acknowledgements.

The assistance and co-operation of the farmers on whose land these trials were conducted, is gratefully acknowledged.

CONTROL OF PTERIDIUM AQUILINUM L. WITH 4-AMINO-3,5,6-TRICHLORO-PICOLINIC ACID

J. Lhoste, F. Vernié, A. Casanova
Laboratoire des Pesticides - Procida
17, rue Soyer - Neuilly, France

Summary: From a series of trials conducted during two years, we concluded that it was possible to use 4-amino-3,5,6-trichloro-picolinic acid in pre- and post-emergence treatments.

INTRODUCTION

The chemical control of bracken is still presenting a very difficult problem. For this reason it was thought that it would be of interest to test 4-amino-3,5,6-trichloro-picolinic acid (pichlorame)(1), in comparison with 2-methoxy-3,6-dichloro-benzoic acid (dicamba), as both have been reported by some workers to show promise as bracken killers.

MATERIALS AND METHODS

Two chemicals have been tested :

- 4-amino-3,5,6-trichloro-picolinic acid (potassium salt), at the rate of 2 lb of acid equivalent per U.S. gal.

- 2-methoxy-3,6-dichloro-benzoic acid (dimethyl-amine salt) at the rate of 4 lb per U.S. gal.

The used dosages are given in gram of acid equivalent, i.e. pichlorame and dicamba, per hectare.

A logarithmic field plot sprayer "Type van der Weij" with constant pressure was used. For treating expanded fronds, it was equipped with a one nozzle spraytube. For treatment carried on shortly after emergence, it was equipped with a sprayboom having a working width of 2 m along which are spaced at 33 cm intervals six nozzles. All applications were made at the rate of 1000 liter/hectare.

Experiments have been conducted according to the method recommended by the "Pteridium aquilinum Group" of the European Weed Research Council.

Treated plots were 3 or 4 metres wide and 10 metres long. Trials were laid out at St-Aubin de Cretot, Seine Maritime, (Experiment 1) and at Rambouillet, Seine-et-Oise, (Experiments 2 and 3.

---

(1) Pichlorame : Common name proposed by A.F.N.O.R.

For each chemical, two replicates were made there being one control plot per replicate.

RESULTS

Experiment 1

Pichlorame only was tested at the rates of 2450 g and 4900 gram per hectare. Date of treatment : July 11th, 1963. Bracken fronds were 1,50 m to 2 m high.

A few days after the application, distortions were observed at the terminal portions of the fronds. Increasing rates resulted in greater distortions but no detailed evaluation was made at that time.

More than a year after the treatment, on 28th August, 1964 counts and weights of the fronds were made. Results are reported in table I.

Table I

Effect of pichlorame on bracken

Date of treatment : 11th July, 1963
Frond counts and weights : 28th August, 1964

Herbicide	Rate g/ha a.i.	Bracken sq m number	Bracken sq m weight	Mean weight gram/frond	Percentage reduction in frond (1) number	Percentage reduction in frond (1) weight
pichlorame	4900	1	90 g	90	94.5	97.5
pichlorame	2450	3	285 g	95	84.4	91.7
control	-	18	3402 g	189		

(1) compared with control

Considering the results which were obtained at St-Aubin, further tests were laid down in 1964 at Forêt de Rambouillet.

Experiment 2

This experiment has been carried on at Forêt de Rambouillet, Seine-et-Oise, France.

Pichlorame and dicamba were compared.

Pre-emergence treatments were carried out on a soil previously prepared with a "girobroyeur" or with a "Debroussailleuse landaise". (see next page)

Post-emergence treatments were laid down before and after bracken had developed into expanded fronds. The used rate was lower than that which was applied in the 1963 experiments.

Pre-emergence treatment results are shown in table II.

Table II

Pre-emergence treatment results after working with a "Girobroyeur" (1) or a "Debroussailleuse landaise" (2)

Date of treatment : 6th May, 1964
Frond counts and weights : 18th August, 1964

Herbicide	Methods of cultivation	Rate g/ha a.i.	Bracken sq m number	Bracken sq m weight	Mean weight g	% reduction in frond weight (1)
dicamba	GB (2)	1920	13	766	58	68.6
	DL (3)	1920	36	1240	34	0
pichlorame	GB (2)	1920	19	700	36	71.3
	DL (3)	1920	35	270	7	74.8
control	GB (2)	-	23	2436	106	
	DL (3)	-	32	1071	33	

(1) compared with control
(2) GB = Girobroyeur
(3) DL = Débroussailleuse landaise

Following pre-emergence treatments, the most part of the fronds were growing up but they appeared distorted, woody and tough. Then scorch was observed at the apical buds. Finally, all the fronds were destroyed.

Working with "Débroussailleuse landaise" resulted in an increased number of shoots but they remained stunted especially after an application with pichlorame. When using the "Girobroyeur" successful results were obtained as early as the first year.

Applications with pichlorame appeared to give better results than with dicamba.

---

(1) Girobroyeur: Rotary cultivator mechanically propelled, with rotary blades. The bracken is killed by pounding it down to the surface.

(2) Débroussailleuse: Special plough wich is working out the rhizomes.

Post-emergence treatment results are given in table III.

Table III

Post-emergence treatment results

Frond counts and weights : August 18th, 1964

	Rate g/ha a.i.	Bracken sq m number	Bracken sq m weight	Mean weight g	Percentage reduction in frond weight (1)
Application on non expanded fronds - 6th May, 1964					
dicamba	1920	24	1086 g	45	33
pichlorame	1920	22	526 g	23	67,6
control	-	21	1620 g	77	-
Application on expanded fronds - 6th May, 1964					
pichlorame	1920	16	333 g	20	57,7
control	-	15	786 g	52	-
Application on fronds fully open - 6th June, 1964					
pichlorame	1920	29	964 g	33	64.9
control	-	34	2746 g	80	

(1) compared with control

DISCUSSION

From our experiments, it appeared that the size of the plots which is recommended by the "Pteridium aquilinum group" of the E.W.R.C. is too small. In fact, killed fronds were also found outside of the treated area, as pichlorame can be translocated by tillers. It seems necessary to use plots 15 x 15 m in side, with border discards being 5 m minimum.

In order to prevent, to a largest possible extent, reinfestations due to untreated areas, ploughing along the testing plots is also recommended, so as to break up tillers and to avoid their spreading from a plot to an other plot.

Post-emergence treatments conducted during the past two years with pichlorame gave satisfactory results when applied at the rate of 2450 g minimum. At 1920 g, a rather good effect was noted as early as the first year of treatment.

From the appearance of the tillers, it seems that the chemical is persistant.

Pre-emergence treatments conducted during 1964 gave most promising results. Nevertheless, it would be advisable to carry on further experiments concerning the effect of mechanical work on pichlorame application.

Pichlorame must be applied with care as it is efficient on quite a number of woody species and particularly, we have recorded injuries on Pinus sylvestris L. and Betula alba L. On the contrary, Quercus robur L. appeared to be resistant to this chemical.

Research Summary

BRACKEN CONTROL USING DICAMBA

J.R. Aldhous
Forestry Commission Research Station, Farnham, Surrey

Summary The dimethylamine salt of 2-methoxy-3,6-dichlorobenzoic acid (dicamba) has given complete control of bracken (*Pteridium aquilinum*) for the growing season in the year of treatment when applied in April, May or June at rates from 4 lb a.e. per acre. The bracken remaining at the end of the growing season on plots sprayed at 2 lb a.e/ac. was sparse and seriously malformed. Sprays applied in July or August have caused discoloration and some deformation of bracken.

INTRODUCTION

Hodgson (1964) has reported effective control of bracken in 1963 following treatment with dicamba at 4 and 8 lb a.e/ac. in July and August 1962. In his experiments, the control from 2 lb/ac. was variable.

Information from the Velsicol International Corporation, who kindly supplied the material used in these experiments, indicated that effective first year control might be achieved with early summer applications.

The experiments described below were designed to cover these rates and dates.

METHOD AND MATERIALS

Chemical: An aqueous concentrate of the dimethylamine salt of 2-methoxy-3,6-dichlorobenzoic acid containing 4.8 lb a.e/Imp.gall.
Rate: 2, 4, 6 or 8 lb a.e. in 100 gall. of water/ac. at each date of application.
Date of Application: Towards the end of April, May, June, July or August, 1964.
Plot Size: 3 yards square. Each plot was separated from adjoining plots by a 2 yard buffer, and was replicated twice on each site.
Method of Application: Overall spraying onto the ground vegetation and litter and on as much bracken as had emerged at the time of spraying. In June, July and August, the bracken received practically all the spray. In April there was very little above the ground at any site.

Sites: Four sites were selected, all covered with dense bracken. None was planted with young trees.

Rogate Forest (near Liss, Sussex). The site is on a sandy podzol over Lower Greensand with almost pure bracken reaching 3-4 ft. in height. The rhizomes are mainly between 3 and 6 ins. below the soil surface. The site was heavily burned 6 or 7 years ago. Other species include *Betula verrucosa* seedlings, *Calluna vulgaris* and *Erica tetralix*. Together, the ground cover of other species did not exceed 5%.

Forest of Dean (Gloucestershire). A loamy brown forest soil over Coal Measures. Bracken here reaches 4-6 ft. in height, with rhizomes mainly between 3 and 13 ins below the soil surface. The vegetation under the bracken was irregularly distributed but covered between 10 and 50% of the soil surface, and consisted mainly of Agrostis tenuis with some Holcus mollis, Chamaenerion angustifolium, Viola sp. Digitalis purpurea, Rubus fruticosus and Rubus idaeus.

Gwydyr Forest (near Betws-y-Coed, Caernarvonshire). A silty brown forest soil over Ordovician shales. Rhizomes are mainly between 8 and 12 ins.below the soil surface and the fronds grow to between 4 and 6 ft. tall. There is a 60-100% grass cover under the bracken, mainly Agrostis canina and Holcus lanatus with occasional Rubus idaeus and Sorbus aucuparia.

Brendon Forest (near Minehead, Somerset). The site is on a brown forest soil over Devonian shales. The bracken reaches between 3 and 5 ft. in height and the rhizomes mainly lie between 6 and 9 ins. The site has a mixed vegetation cover of grasses, covering up to 60% of the soil surface under the bracken with a little Rubus fruticosus, Rosa sp. and Endymion nonscriptus,etc.

RESULTS

The succeeding paragraphs describe results in mid-September 1964. On all sites very similar results were obtained. By far the biggest response was associated with date of application. Rate of application appeared to be less important.

April Treatments: Bracken was only just starting to come through when the plots were sprayed. On all sites, plots sprayed at 6 and 8 lbs/ac. a.e. contained no live fronds of bracken in September. There were one or two green stems per square yard but these were coiled like springs and had not expanded at all. At Rogate, there were no expanded fronds on the plots sprayed at 4 lb/ac. in April, but only coiled stems at ground level. On the other sites, there were 1 or 2 stunted and deformed fronds per square yard on plots sprayed at 4 lb/ac. and between one and eight fronds on plots sprayed at 2 lb/ac. There were more fronds standing on grassy areas than where the soil was bare of vegetation. Both in these and in later treatments, fronds or parts of fronds which were growing at the time of treatment showed acute curving of all stems, reflexing of the segments (i.e. the small leafy parts of the frond)and die-back of the tips.* The few fronds which emerged after treatment were stunted, the pinnules (i.e. those parts of the stem bearing segments) expanded incompletely or failed to develop at all, and those segments which did develop were reflexed and smaller than usual.

May Treatments: At the time of spraying, the bracken was growing rapidly, stems were up to 1½ or 2 feet tall, but none of the fronds had expanded much. In September, treated fronds were blackened and distorted. On all plots treated at 6 and 8 lb/ac. there were only one or two green stems remaining. Plots treated at 4 lb had up to two fronds per square yard remaining and plots treated at 2 lb had up to five fronds per square yard. All these were stunted and deformed like those on plots treated in April.

June Treatments: The fronds of the bracken were expanding rapidly at the time of these treatments and at Brendon were almost fully developed. In September the lower parts of the stems (presumably those parts which were mature at the time of treatment) were not distorted. Most of the leafy part of all the fronds were twisted, deformed and browned. The degree of browning was dependent on the rate of application, and ranged from about 60% of the leafy parts browned on plots sprayed at 2 lbs to 100% on plots sprayed at 8 lbs. Many of the main stems remained green even though the foliage was brown.

July Treatments: Fronds were almost completely developed when the July treatments were applied. At three sites, the tips of fronds were distorted and the other parts browned, the extent of the browning again being dependent on rate but not being quite as severe as on plots treated in June. Many Gwydwr stems remained green./ All the bracken went brown and started to collapse and grass was scorched. The reason for this different response is unknown.

August Treatments: These were applied when the bracken was fully developed. In September, only a few weeks after treatment, very little response by the bracken could be seen at any site. There was some browning or bronzing and this was more marked on the plots treated at the heavier rates.

Movement of Dicamba

Particular note was taken of the behaviour of bracken along plot boundaries. On all sites many bracken fronds outside plots treated in April and May showed clear symptoms of dicamba damage, being stunted and failing to expand fully. Most fronds emerging up to twelve inches away were affected, as were several up to eighteen inches. In September there were no healthy fronds inside any plot treated in April or May. This evidence suggests that dicamba can move along rhizomes and agrees with Hodgson's observations (Hodgson, 1964).

Effect on other Species

Woody species growing at the time sprays were applied were generally defoliated and some species, e.g. Betula sp. and Calluna vulgaris, killed. Others, e.g. Sorbus aucuparia and Rubus idaeus recovered. Foliage of Japanese larch (Larix leptolepis) growing alongside the site at Gwydyr - which was in a ride separating two plantations - was damaged, the very young foliage on elongating shoots being killed and the older foliage reflexed. Grasses were not affected.

DISCUSSION

These results indicate that complete control of bracken for at least one growing season can be achieved by spraying dicamba at 4 lb/ac. in April or May. On the plots treated at 2 lb/ac. in April and May, the growth of bracken has been checked to such an extent that it could provide only very little competition for any species growing on the site. If the control of bracken achieved in these experiments persists and these results are confirmed in other years, this chemical will have an important role both in hill farming and in forestry.

Assessments will be made of the growth and number of fronds, and their height and appearance in 1965. Young forest trees will be planted on the plots, some in Autumn 1964 and some in early Spring 1965.

Reference

HODGSON, G.L. (1964) Sodium 3,6-dichloro-2-methoxybenzoate for the control of bracken (Pteridium aquilinum (L) Kuhn): Results of Preliminary Trials. Weed Res. 4 167-168.

Research Summary

METHODS FOR THE RAPID BIO-ASSAY OF HERBICIDES

C. Parker
A.R.C. Unit of Experimental Agronomy, University of Oxford

INTRODUCTION

The persistence of herbicides in the soil is a problem which deservedly is receiving increased attention, and various methods of assay have been developed. Chemical assays are rarely usable on soil samples without elaborate extraction procedures, so bio-assays are more commonly employed. The simplest method is to measure the growth of plants sown in pots or tins of the treated soil. Holly and Roberts (1963) have described in detail a method using ryegrass (Lolium multiflorum Lam.) for the assay of substituted urea and triazine herbicides. Owing to the delayed effect of these herbicides until some time after emergence, 3 weeks' growth is required before assessment is possible. This period may not be too long in relation to the rate of breakdown for these herbicides, but for others, which might be lost to a significant extent during the course of the assay a quicker assay is highly desirable.

For chloropropham, Roberts and Wilson (1962) have described a rapid test using root-growth of buckwheat (Fagopyrum esculentum Moluch); germinated seed is placed on the surface of treated soil in pots, and after 3 days the plants are turned out and root length is measured.

The following summary gives an account of a root growth assay which has certain advantages over the buckwheat method and which may be modified for assay of shoot-inhibiting herbicides. A method has also been devised for the rapid assay of substituted ureas, triazines and uracils which characteristically are slow to cause visible damage.

METHOD AND MATERIALS

Root-growth assay

Treated soil is weighed and water then added to bring it to a predetermined moisture which is adequate for root growth, but does not result in loss of structure on mixing. The quantity weighed and mixed is such that it just fills a plastic Petri-dish.

The test plant which has been found suitable for a range of root-inhibiting herbicides is sorghum (Sorghum vulgare, var. Sudax SX-11). This plant has advantages of robustness, ease of handling and rapidity of growth. Seeds are pre-germinated on moist filter paper for 16-20 hours at 25°C, by which time the radicle has just emerged. Ten seeds in a row are then pressed into the surface of the soil in the Petri-dish, with the embryos uppermost and the lid taped firmly on. The dishes are mounted in a nearly vertical position such that the roots all grow across the soil surface against the lid. Careful filling and levelling of the soil in the dishes is essential to obtain good contact of the lid and hence the roots with the soil. The dishes are kept overnight in the dark, at 25°C. By morning, up to 1 cm. of root growth will have occurred and the positions of the root tips are marked with a grease pencil. The dishes are then returned to the incubator for a further 24 hours, by which time roots in the control dishes will have reached 30-35 mm beyond the mark, and all roots are measured. The assessment can usually be made without the necessity of opening the dishes.

Shoot-growth assay

The procedure is very similar to that for root growth, with the following differences:- (a) the seeds are sown lower in the dish; (b) the dishes are tipped so that the shoots instead of the roots grow against the lid; (c) the assay takes longer, up to 4 days, and if there is any danger of loss of herbicide by volatility, then the dishes should be sealed with tape.

If the dishes are kept in the dark, only growth of the mesocotyl will occur. This may be suitable for certain herbicides, especially for high concentrations of some of the root-inhibiting herbicides, but for the thiolcarbamates, the dishes must be exposed to light at some stage in order to stop mesocotyl growth and promote the growth of the more sensitive leaf tissue.

A further modification of these techniques has been made for studying the relative importance of entry of herbicides via the shoots and via the roots of germinating seedlings. For this purpose, two square Petri-dishes are used, notches being made leading from one to the other. Sorghum seedlings 1-2 cm long are placed across the notches with the shoots in one dish and roots in the other. A seal is effected using a silicone rubber compound. Herbicide can be applied separately to the roots and/or to the shoots and the moisture conditions may also be varied. This technique has been used to study the effects of herbicide volatility and soil moisture on the importance of shoot uptake of herbicides by emerging seedlings. This work is to be reported in full elsewhere.

Assay for triazines, ureas and uracils

These herbicides characteristically inhibit the Hill reaction *in vitro* and are believed to act in the plant by inhibition of the "light reaction" of photosynthesis. The bipyridyl herbicides, paraquat and diquat, on the other hand produce their most rapid effects as a result of reduction and hence activation by this "light reaction" (Mees, 1960). Inhibition of the "light reaction" by triazine or other herbicides can therefore be demonstrated by their retardation of paraquat (or diquat) action in the light. A quantitative assay method based on this principle has been developed as follows:- 100g (dry wt.) of treated soil is made into a slurry by the addition of 100 ml water. The slurry is stirred thoroughly prior to the addition of a number of frond of *Lemna minor*. The fronds are left to stand in the slurry to allow uptake of herbicide. After about 24 hours 0.2 ml of 24% paraquat solution (or more or less depending on the adsorptive capacity of the soil) is added to each slurry, and mixed carefully but thoroughly, leaving the *L. minor* in place. The slurries are then placed under bright uniform lighting, in order to encourage the rapid and characteristic symptoms of paraquat. After 6-20 hours depending on the light intensity, symptoms will have developed on fronds whose photosynthetic processes have not been interferred with by soil-applied herbicide, whilst higher residual amounts of triazine-type herbicide will prevent the development of paraquat symptoms. Assessment is made by observing and scoring the degree of "scorch" and/or bleaching on each frond, and plotting the mean scores against dose, graphically. A standard series of slurries provides a reference curve, from which the concentration in unknown samples may be estimated.

RESULTS

Most work on the sorghum root and shoot-growth assays has been carried out on herbicide solutions applied to silica sand, and results of these tests are shown in Table I.

Table I

Concentration of herbicide (ppm) required to cause 50% inhibition of roots, the extension growth of shoots or leaves of sorghum.

Herbicide	Root growth (40 hours)	Shoot growth (64 hours, dark)	Leaf growth (88 hours, light)
Dichlobenil	0.07	0.26	-
Dicamba	0.11	-	-
2,4-D	0.12	-	-
Trifluralin	0.20	-	-
Amiben	0.25	-	-
Picloram	0.6	-	-
Diphenamid	0.75	-	-
Chlorpropham	1.25	10	-
Propham	16	-	-
CDAA	-	-	3
CDEC	-	-	1-2
EPTC	-	-	0.3-0.9*
Di-allate	-	-	0.5-1.0*
Tri-allate	-	-	1.0-4.0*

* Variable more sensitive if placed in the dark for the first 36 hours of the assay. - indicates no precise results available.

Sorghum roots are most sensitive to dichlobenil (and also the related 2,6-dichlorothiobenzamide). A number of other herbicides cause 50% inhibition at well below 1 ppm, but chlorpropham and propham are relatively inactive. For these compounds a more sensitive test plant such as oat could be substituted. Shoot-growth assays carried out in the dark, in which total shoot length (i.e. mainly mesocotyl) is measured, provide an extension of the range of sensitivity to higher concentrations of dichlobenil, chlorpropham and also trifluralin. This may be of value when treated soil is not diluted sufficiently and proves to cause complete inhibition of root growth. The shoot-growth assay carried out in the light provides a rapid assay for the thiolcarbamates and also CDAA and CDEC. Sensitivity depends somewhat on light conditions, and in any case does not extend to very low concentrations, but it is again probable that oat would provide a satisfactory alternative species.

There has been considerably less experience as yet with the assay for substituted triazines and ureas, but it has proved possible to obtain satisfactory dose response curves with linuron and atrazine, and sensitivity extends down to concentrations of 0.1 ppm wt./wt. dry soil, equivalent to 0.05 Kg/Ha (less than 1 oz/ac) incorporated to 5 cm (2 in.) depth.

DISCUSSION

The root growth assay described above is considered to have the following advantages:- (a) enclosure of the assay sample in a Petri-dish allows control over the moisture content throughout the assay, and (b) lessens risks of loss of volatile herbicide and contamination of the incubator or growth chamber; (c) visibility allows continued observation and permits choice of optimum time of assessment which is of special value where temperature cannot be precisely regulated; (d) compactness allows a large number of samples to be assayed in the restricted space of an incubator or other constant environment, and (e) only slight modification is required to change it to a shoot-growth assay. Care is required in the packing of the soil in the dishes, but with some practice and with constant light and temperature conditions, results are found to be precise and reproducible for assays of both root and shoot growth. The sensitivity of the sorghum is good for a number of herbicides, and with the substitution of oat for certain others, satisfactory assays are possible on a very wide range of herbicides, causing inhibition of either root or shoot growth.

Those inhibiting photosynthesis, such as the substituted triazines, ureas and uracils may be detected and measured satisfactorily, it is believed, using the slurry method. This method may not prove to be as sensitive or as precise as the ryegrass method described by Holly and Roberts, but its rapidity (24-48 hours) should make it at least of value in providing a quick check of the approximate level of herbicide contamination, from which suitable dilution ranges or choice of test species may be derived. Meanwhile, it is hoped that further refinement of the technique will lead to greater sensitivity and precision.

References

HOLLY, K. & ROBERTS, H.A. (1962). Persistence of phytotoxic residues of triazine herbicides in soil. Weed Res. 3 (1), 1-10.

MEES, G.C. (1960). Experiments on the herbicidal action of 1,1'ethylene-2,2'-dipyridilium dibromide. Ann. Applied Biol. 48 (3), 601-12.

ROBERTS, H.A. & WILSON, B.J. (1962). Note on the bio-assay of chlorpropham in soil. Weed Res. 2 (1), 60-65.

Research Summary

THE GLASSHOUSE EVALUATION OF GRANULAR HERBICIDES

P. A. Gabbott and D. H. Payne
"Shell" Research Limited
Woodstock Agricultural Research Centre
Sittingbourne, Kent.

INTRODUCTION

In recent years the application of herbicides in granular form has increased considerably but research into the relationship between chemical, physical and herbicidal properties of various granular formulations has not permitted many generalisations or conclusions as to their relative performance. To date most comparisons have been made by means of field trials, which are necessarily expensive, time-consuming and involve many uncontrollable variables, e.g. climatic conditions and soil type, which may alter the effectiveness of the various formulations. Such trials are of course important for this very reason but rapid and adaptable glasshouse methods of assessment under controlled conditions allow a better understanding of the factors affecting the relative inherent toxicities of different granular formulations, and serve as a valuable guide to field-testing.

The present procedure was designed as a means of evaluating the pre-emergence activity of various granular formulations of WL 5792 (2,6-dichlorothiobenzamide) using mustard (Sinapis alba) as the test species, but the principles of the method are adaptable to a wide range of toxicants and test species.

METHODS AND MATERIALS

Preliminary experiments using small-scale glasshouse plots had shown that at low dose rates, application of granules by "random scattering" (commercial size range, 14-60 BS mesh) gave an unacceptable variation in biological response due to uneven distribution of toxicant over the soil surface. In the present method this has been reduced by restricting the range of granule size (22-25 BS mesh) and "placement" of the granules according to a pre-determined square pattern. Thus for a given dose of toxicant the spacing between individual granules is given by the relationship:-

$$S = \frac{3.6}{\sqrt{\dfrac{A \times 9372}{B \times C}}}$$

where S is the granule spacing (inches); A is the required dose (lb toxicant per acre as a decimal); B is the toxicant content of the granules (as a percentage wt/wt) and C is the weight of 100 granules (milligrams).

Plastic seed trays, 8 in. x 14 in. x $2\frac{1}{2}$ in. are partitioned into two equal plots by means of a metal divider and then filled with a potting medium, the top inch of which has been intimately mixed with mustard seed at the rate of 500 seeds per tray. The trays are sown and watered to "field capacity" in the morning and treated in the afternoon.

Granules representing the 22-25 BS mesh fractions of the various formulations under evaluation are applied at the desired doses by means of a special applicator. This consists of a series of interchangeable brass grids drilled with small holes (0.4 mm diameter, No. 78 BS drill) at the appropriate granule spacings. These cover the range 0.24 in. - 1.60 in. in units of 0.04 in. (giving doses of 10% granules equivalent to approximately 7.2 and 0.16 lb a.i. per acre respectively). Outside this range, the granules can be applied successfully by hand, either individually (lower range) or by "random scattering" (higher range). Each grid can be fitted into a metal cover and held in place by means of plastic sleeves. The apparatus is assembled with the grid uppermost and a slight vacuum applied to the cover. A quantity of granules is spread over the grid surface and on inverting the cover the number corresponding to that particular dose is held in place by suction. These are then deposited on the soil surface by releasing the vacuum.

After covering with a layer of fine grit to prevent lateral displacement of the granules during overhead watering the trays are kept in the glasshouse at 20-25°C and watered daily. At the end of the test period (usually 10-14 days) the shoots are cut at soil level, weighed and the percentage reduction in fresh weight of shoots calculated for each dose. In order to eliminate "edge-effects", a metal quadrat 5 in. x 5 in. is placed in the centre of each plot and the yield data are based only on the plants harvested within this area.

The relative herbicidal activity of the various granular formulations is then evaluated by probit analysis of the above data.

DISCUSSION

For weed control by soil-acting herbicides granules would appear to have a number of advantages over the more conventional spray formulations arising from:-

(i) their more efficient penetration of the foliar cover in established weed and/or crop populations

and (ii) the degree of control that can be exercised over the release of toxicant into the soil by modifications in formulation.

The distribution of the herbicide over the soil surface will depend on the size of the granules, toxicant content and the rate of application but to be effective after application the toxicant must also be leached from the granules and pass to its site of absorption by the plant.

Recent physico-chemical studies in the laboratory have shown that the rate at which a toxicant is leached from a granular formulation by rainfall may depend upon its concentration in the granules, their size and the nature of the components used in their preparation. Furthermore, the rate is affected by the climatic conditions under which the leaching is carried out e.g. temperature and duration and intensity of the rainfall. Under conditions approximating to normal field usage (i.e. where the quantity of formulation per acre is varied according to its toxicant content) the release of toxicant decreases considerably as the toxicant content is increased due to a reduction in the number of granules per unit area. Again the rate at which the toxicant is released decreases as the size of the granules is increased but this appears to be related not to the decrease in number of granules per unit area but to the decrease in their surface area. Such factors would be expected to control the biological effectiveness of the various formulations due to the accompanying differences in the relative distribution of the toxicant and the weeds that are being controlled.

The nature of the toxicant itself also has an important bearing on the relative effectiveness of the different types of formulation, thus compounds with a low vapour pressure, high melting point and very low water solubility are likely to be less effective when formulated as granules than as sprays (Schuldt et al 1961).

By accurately controlling their distribution over the soil surface the proposed method of evaluating herbicide granules in the glasshouse enables the above factors to be assessed in terms of biological activity, both as main effects and as first or higher order interactions. The method can be readily extended to include a range of environmental and climatic factors, e.g. soil type and rainfall regime, together with their various interactions. Ultimately the value of such studies will depend on the extent to which they improve the extrapolation of physico-chemico data obtained by the formulation chemists to the complex situations encountered in the field.

Of interest in this respect are the recent field studies of Tisdell and Ilnicki (1962). These authors investigated the effect of toxicant content, granule size and rate of release on the behaviour of 2,4-D granules in corn and concluded that at doses of 1.5 lb per acre or below all of these parameters could be important from the point of view of weed control and/or corn injury, but that at higher rates of application the differences were obscured. Other authors, however, have suggested that such differences are at the best marginal and therefore of little consequence at rates of application giving effective weed control (Lovely, 1960). Much of the conflict surrounding such studies would appear to arise from two factors viz:-

(i) present field equipment has not permitted very accurate distribution of granules over relatively large areas

(ii) to date the preparation of granules by impregnation methods has allowed only limited control over their physical and chemical properties.

There are indications, however, that new equipment and formulating techniques will lead to improvements in both these fields and allow the development of more effective methods of using granular herbicides.

REFERENCES

Lovely W.G. (1960) Proc. 17th North Central Weed Control Conference 11.

Schuldt P. H., Limpel L. E., Galloway A. L. and Lamont D. (1961) Proc. North Eastern Weed Control Conference, 15, 48.

Tisdell T. F. and Ilnicki R. D. (1962) Proc. North Eastern Weed Control Conference, 16, 340.

In due course it is intended to submit a full account of this work for publication in "Weed Research".

THE USE OF PARAQUAT AS AN ALTERNATIVE TO PLOUGHING

A.E.M.Hood, D.G.Sharp, D.W.Hall and R.Cotterell
Imperial Chemical Industries Limited,
Jealott's Hill Research Station,
Bracknell, Berkshire.

Summary Two experiments at Jealott's Hill, with winter wheat, compared spraying with paraquat followed by direct drilling into stubble with a conventional system of cultivation. Features of a combine drill designed for sowing cereals without ploughing are described. Yields of grain, using the no-plough technique, compared favourably with treatments which were ploughed and cultivated prior to drilling. Evidence from one trial suggests that spraying before drilling is an essential feature of this new technique. The reduced incidence of disease, especially take-all, under no-plough conditions will be examined with interest in future trials involving continuous cereal growing.

INTRODUCTION

Current practices in the production of most crops are dictated largely, by the necessity to cultivate to control weeds. Previous work at Jealott's Hill (Hood et al., 1963, 1964) has shown that successful cereal crops can be achieved by drilling directly into swards killed with paraquat. Under such conditions, yields compared favourably with conventional systems involving ploughing and cultivating. The experimental work described in this paper shows how the no-plough technique can be applied successfully when one cereal crop follows another.

METHODS AND MATERIALS

Two experiments were completed in 1964 in which winter wheat was sown after either one or two preceding winter wheat crops.

In experiment I, which was a continuation of previously published work (Hood *et al.*, 1963, 1964), Hybrid 46 was sown as the third successive winter wheat crop after permanent pasture. The treatments were:

1. 2 lb of paraquat (= 1 gallon 'Gramoxone' W) in 24 gallons of water per acre sprayed on 18th September 1963. Drilled without ploughing or cultivating.

2. As 1, but ploughed on 1st October and cultivated prior to drilling.

3. No spray. Ploughed on 1st October and cultivated prior to drilling.

All plots were sown on 11th October,1963 and 2 cwt per acre of I.C.I. No.3 fertilizer (10:20:20) were drilled with the seed.

The three main treatments were duplicated in randomized blocks and each plot was split into four sub-plots,each of 0·016 acre for rates of nitrogen fertilizer providing 0,45,90 or 135 lb of N. per acre in the spring.

In experiment II Hybrid 46 was sown as the second winter wheat crop after a ley and the following treatments were compared:

1. 2 lb of paraquat in 24 gallons of water per acre sprayed on 2nd October,1963. Drilled without ploughing or cultivating.

2. No spray. Ploughed on 3rd October and cultivated prior to drilling.

3. No spray. No cultivations.

Sowing was carried out on 12th October,1963 and 2 cwt per acre of I.C.I. No. 3 fertilizer were drilled with the seed.

The main treatments were replicated four times in a randomized block design and each plot was split into two sub-plots,each of 0·016 acre,for levels of nitrogen fertilizer providing 0 or 112 lb of N. per acre in the spring.

In the above experiments a standard drill with disc-type coulters was used in all treatments in autumn 1963. Weights were added to the discs to facilitate penetration on the directly drilled plots. Subsequently, further work was carried out in order to improve both the coulter design and the method of exerting pressure on to the coulter.

RESULTS

1. Observations on the Weed Flora

In both experiments,observations in 1964 showed the weed flora to vary considerably according to treatment. From estimations made during growth and on the stubble after harvest,it was evident that the sprayed/directly drilled plots were less infested with weeds than those plots which had been ploughed. In Experiment II a heavy weed infestation developed and competed with the crop at all levels of nitrogen on the plots which were drilled directly without cultivations or spraying.

In Experiment I the main graminaceous weeds present were meadow fox-tail (Alopecurus pratensis),rough-stalked meadow grass (Poa trivialis), creeping bent (Agrostis stolonifera) and annual meadow grass (Poa annua). The latter three were confined largely to the ploughed treatments whilst Alopecurus pratensis was found only on the unploughed plots and resulted from seed shed in the previous crop. A score of general weediness in mid-July is given in Table 1.

The major grass weeds in Experiment II were P. trivialis, perennial ryegrass (Lolium perenne); couch (Agropyron repens) and P. annua, all of which were found in abundance on plots drilled directly without cultivating or spraying. P. annua and A. repens were frequent on the ploughed areas while only P. trivialis occurred in the sprayed/directly drilled plots. A score showing general weediness in mid-July is in Table 1.

Table 1

General score for weediness in winter wheat in mid-July

	Weed Scoring	
0 = No weed	5 = Moderately heavy infestation	
Method	Experiment I	Experiment II
Sprayed/directly drilled	1·8	0·6
Sprayed/ploughed/cultivated	2·2	-
Ploughed/cultivated/drilled	3·1	2·6
No spray/directly drilled	-	3·8

2. Grain Yields

The results from Experiment I in 1964 are shown in Table 2, together with results from the previous two years of this experiment on the same site using winter wheat. In only the first year of the experiment did the grain yield from the ploughed treatment exceed, by a significant margin, the yield of grain from treatments which were sprayed and drilled directly ($p = 0·05$); this was attributable to the use of a drill with blunt hoe-type coulters which tore up the turf, made rough furrows and caused patchy establishment. In subsequent years, using the standard drill with disc-type coulters, there was no significant difference in yield between the ploughed and the directly drilled treatments.

The grain yields for 1964 were lower than for the previous two years, the incidence of plant diseases being largely responsible. This aspect is discussed later.

Table 2

The effect of pre-sowing technique on the grain yield of winter wheat

Method	1962	1963	1964	Mean
Grain yields in cwt/acre adjusted to 85% dry matter				
Sprayed/directly drilled	55·4	52·9	40·3	49·5
Sprayed/ploughed/drilled	60·7	53·0	35·2	49·6
Ploughed/cultivated/drilled	58·3	52·2	37·1	49·2
Significant difference (p = 0·05)	2·9	n.s.	n.s.	

The results of Experiment II are shown in Table 3.

Table 3

Direct drilling with and without spraying compared with conventional cultivations for winter wheat

Nitrogen fertilizer (lb/acre)	0	112
Grain yields in cwt/acre adjusted to 85% dry matter		
Sprayed/directly drilled	32·2	46·6
Ploughed/cultivated/drilled	27·2	48·1
No spray/directly drilled	27·8	33·3
Significant difference (p = 0·05)	4·1	

In the absence of nitrogen fertilizer the grain yield from the treatments which were sprayed and then drilled directly significantly exceeded the yield achieved by the comparable ploughed treatment. No such difference between these treatments, however, could be detected where 112 lb of N was applied per acre. Where the seed was drilled directly without spraying, the yield of grain was poor both in the presence and absence of applied nitrogen.

3. Incidence of Disease

From observations made on Experiment I during growth it was thought that differences might be developing between treatments in the build-up of disease after three successive years of winter wheat. Samples were collected and assessed for incidence of take-all (*Ophiobolus graminis*), eyespot (*Cercosporella herpotrichoides*), sharp eyespot (*Rhizoctonia solani*) and brown foot rot (*Fusarium* spp.). The results are shown in Table 4.

The percentage of tillers infected with take-all was lower on the directly drilled plots which were sprayed than on plots cultivated in the conventional manner. This reduced incidence of take-all was highly significant ($p = 0{\cdot}001$) whereas the difference in the percentage of tillers infected with eyespot, sharp eyespot and brown foot rot failed to reach significance.

Table 4

Percentage disease infection of wheat tillers (averaged over N. fertilizer rates)

Method	Take-all	Eyespot	Sharp Eyespot	Brown Foot Rot
Sprayed/directly drilled	2·6	26·0	6·7	15·1
Ploughed/cultivated/drilled	20·4	38·2	5·7	9·7

4. Drill Modifications

With a conventional dished disc, as was used in the above experiments, it was found that the shape of the slot, into which the seed was placed, was not ideal. The higher the drilling speed, the greater was the tendency for the sides of the slot to be disturbed and for the slot to be left open. Various coulter designs were therefore tested to find one more suitable for drilling cereals into uncultivated land.

A coulter system was chosen for further development which gives a vertical slot approximately $\frac{1}{2}$ in. wide, allowing the seed and fertilizer to be introduced to the soil together at a depth of from 1 - 2 in. The design consists of a small diameter (8 in.) straight disc followed by a knife coulter, both of which are mounted rigidly to a coulter arm. The disc cuts through the trash or root mat forming a slit whilst the knife opens up the slit to allow introduction of the seed and fertilizer. The knife coulter is shaped to facilitate a natural pull into the soil, the disc acting as a depth control unit preventing the knife penetrating to too great a depth.

Coulters based on this principle were fitted to a modified Massey Ferguson 732 drill and tested in the spring of 1964. Its action was satisfactory except where loose straw remained on the stubble or where excessive vegetation was left. Drilling speeds of 4 - 6 mph were more satisfactory in preventing a build-up of trash on the coulters than slower speeds. Emergence counts showed comparable results to those obtained under ploughed conditions.

DISCUSSION

The experiments described above and previously (Hood et al.,1963,1964) indicate that satisfactory cereal crops can be achieved after grass or previous cereals using minimum cultivation techniques in which weed control is achieved by spraying with paraquat. Results from one trial, and evidence from previous workers (Charles,1962), show that the inclusion of the spray is an essential part of this system.

Although the weed flora that developed within the crop varied according to the cultivation system adopted, it was usually found that spraying and drilling directly resulted in less weedy crops than after ploughing especially where nitrogen was applied. Such a system adopted continuously must inevitably lead to the minimum of exposure of buried weed seeds.

The disease aspects cited give new significance to these trials although the reasons for the reduced incidence of take-all on the directly sown plots remains obscure at present.

The problem of obtaining good drill performance in soils which have not been ploughed or cultivated following grass or arable crops (but which have been sprayed with paraquat to remove vegetation) is related to the need for exerting greater pressure on the coulters to enforce adequate penetration into the soil. The prototype drill with an entirely new coulter design, which is described above, was developed especially to suit the direct-drilling operations and in tests under a variety of conditions it performed satisfactorily.

Acknowledgments

The authors express their appreciation to Mr.D.B.Slope, of Rothamsted Experimental Station, for collecting samples and assessing the diseases appearing in Experiment I and to Mr.P.A.Collier, of Jealott's Hill, for statistically analysing the data.

References

CHARLES,A.H. (1962) Pasture Establishment by Surface Sowing Methods Herb.Abs.32,175-181.

HOOD,A.E.M. et al. (1963) Destruction of Pastures by Paraquat as a Substitute for Ploughing. Nature,Lond.197,748.

HOOD,A.E.M. et al. (1964) Crops Grown using Paraquat as a Substitute for Ploughing.Nature,Lond.201,1070-1072.

THE USE OF TRIAZINE HERBICIDES TO REPLACE CULTIVATIONS IN DRYLAND SORGHUM IN ISRAEL

Menashe Horowitz
Division of Weed Research, Volcani Institute of Agricultural Research, Israel*

Summary On non-irrigated land in Israel, sorghum is normally sown after a winter fallow. A single herbicidal application at the beginning of the winter rains controlled both the winter weeds appearing during the fallow period, and also the summer weeds appearing between the sowing and harvest of the sorghum. The most persistent weed control was achieved by spraying atrazine or propazine at 1.5 kg/ha. It appears that a single application of either of these herbicides could replace all the winter and summer cultivation needed during one year. Such a technique could be fitted into the existing dryland cropping rotation provided that, at the end of the year, no phytotoxic soil residues remained, which might affect the succeeding winter crop.

INTRODUCTION

The Israeli climate is characterised by a mild and rainy winter, from November to April, followed by a hot and absolutely dry summer. Cropping systems of arable land in Israel depend on water supply: where water and irrigation equipment are available, an irrigated cropping system is used, but for other fields, dryland rotations are needed, relying entirely on natural rainfall. Sorghum, one of the most important summer crops in Israel is grown on irrigated and on non-irrigated land.

On irrigated sorghum, pre-emergence or post-emergence spraying with atrazine provides satisfactory control of most annual weeds. This treatment is already widely used in Israel for irrigated sorghum, but it does not suit the dryland crop where soil-moisture conditions and the weed population are very different.

On dryland with sufficient rainfall the following triennial crop rotation is commonly used: winter cereal (wheat or barley) - winter legume (vetches and clover) - winter fallow - summer crop (sorghum or maize). The order of the two winter crops may change but a winter fallow preceding the summer crop is a regular feature. During the winter fallow several cultivations are needed to eradicate the weeds which consume water and nutrients and to prepare a suitable seedbed for the summer crop. In years when the winter rains are heavy, it may be difficult to achieve a satisfactory seedbed preparation by the appropriate planting date for the summer crop. There is consequently a delay in sowing followed always by a serious reduction in yield.

Recently aerial sprays of mixtures of dalapon and 2,4-D have been tried in fallow land against established winter weeds which could not be controlled by mechanical means. In order to be successful against the weeds and avoid residue damage to the following summer crop, the treatment

---

* Temporary address: A.R.C. Weed Research Organisation, Kidlington, Oxford.

must be carried out before the beginning of February. This necessity for exact timing plus the danger of drift onto nearby susceptible crops limits the practical usefulness of this treatment.

Dryland sorghum is generally sown into the moist soil in April, and grows without further watering, except for light showers which sometimes occur until May. Under these conditions soil-acting herbicides applied at planting do not usually get the necessary moisture to activate them or to leach them down to the roots of the weeds. The situation is made more difficult by the fact that the weeds appearing in the dryland summer crop are mostly deep-rooted annuals or perennials.

Weeds in the summer crop are severe competitors for water, which is the limiting factor under dryland conditions. Cultivation is the usual method of weed control in sorghum, but only controls weeds growing between the crop rows. Post-emergence sprays of 2,4-D control most of the summer weeds, but owing to the sensitivity of the sorghum during the early stages of growth, they cannot be used to control weeds during the first month. They also present a drift hazard to neighbouring crops. For reasons given above, pre-emergence triazine sprays are inefficient.

The purpose of the present study therefore was to examine the possibility of using triazine herbicides known for their selectivity in sorghum and for their long persistence in soil, as early winter sprays, in the hope that they would control weeds throughout the winter fallow period up to crop planting. Further, it was hoped that having been leached into the soil by the winter rains, the same triazine application would control deep-rooted summer weeds from the time that the sorghum was planted until harvest.

METHODS AND MATERIALS

The experiment was carried out at the Neve-Yaar Experiment Station, North-Israel, on a brown alluvial soil containing about 67% clay, 2% organic matter and 10% lime. The field had been cropped on the typical triennial dryland succession described above: a legume had been harvested in the summer of 1962, after which the land had been subsoiled.

The herbicides were applied to a dry and levelled soil, on 23.11.1962 and the first rain after treatment fell 13 days later. The total precipitations from then until the last rain of the winter, on 27.5.63, was 497 mm. None of the plots received any cultivation during the winter, but before planting sorghum, on 10.3.63, the whole field, including all the experimental plots, was ploughed to a depth of 15 cm and disked. In fact, on the plots which received the more successful treatments it would have been possible to plant the crop without any further seedbed preparation. Sorghum (variety Hybride Hazera 610) was planted on 4.4.63 in rows 1 m apart. None of the plots received any supplementary mechanical treatments until harvest, at 15.8.63.

Three triazine herbicides were tested: simazine, atrazine and propazine. The two former were applied in 50% wettable powder and 2% granular formulations, and the last as a wettable powder only, since no granular formulation was available. Two types of control were included among the treatments: a) controls which received a mixture of dalapon at 3.2

kg/ha + 2,4-D amine at 1.0 kg a.e./ha to the established winter weeds, on 8.2.63 and no further treatment throughout the summer; b) controls which received no weed control treatments at all. The treatments were replicated four times on plots 3 m x 20m arranged in randomised blocks.

The sprays were applied at a volume of 400 l/ha from a knapsack sprayer fitted with Tee-Jet 8001 nozzles; the granules were mixed with sand of similar particle size and uniformly broadcast by hand.

The development of the weeds and sorghum was assessed by visual rating. In addition all the weeds on the plots were cut off at ground level and weighed green a) at the end of the winter just before ploughing (3.3.63) and b) in the summer just before harvest (26.7.63).

After harvest, soil samples were taken from the 0-10 cm, 10-20 cm and 20-30 cm depths in the plots sprayed with the higher dose of the three triazines, and the controls, and bio-assayed for residual phytotoxicity. The samples were stored, air dry, in the laboratory till December 1963 when each sample was divided into three sub-samples which were put into waxed paper containers. Ten seeds of Kanota oat were sown in each container, and three weeks after emergence the above-ground parts of the plants were harvested and their dry-weights recorded. Several containers from the soil-layer 20-30 cm were accidently damaged and results from this layer are therefore not included in table 3.

Wheat (variety Florence x Aurore) was sown in December 1963 in the whole experimental field, and residual effects could be observed visually during its growth.

RESULTS AND DISCUSSION

The recommended doses of atrazine and simazine for use on sorghum or maize in Israel are up to 0.5 kg/ha. Since partial decomposition of the herbicides applied in this experiment could be expected to occur during the wet and mild winter before crop planting, the doses tested were two and three times those normally recommended.

1) Effect on weeds

As shown in table 1 the triazine treatments were strikingly effective against winter weeds before crop planting and against summer weeds after planting.

a) Winter weeds - The winter weeds were mostly annuals: gramineae (Phalaris paradoxa, volunteers of wheat and barley) formed the bulk of the weed population but broad-leaved species were also present including Beta vulgaris, Calendula arvensis, Silene aegyptica, and several cruciferae and umbelliferae. At the end of the winter it was apparent that the triazine herbicides had considerably reduced the number of established weeds and checked their growth (see table 1). Best results were obtained with higher rate of atrazine and propazine, whereas simazine was less active against the gramineae.

Table 1
Effect of treatments on weeds

Treatment a.i. kg/ha (1)			Winter weeds		Summer weeds
			Rating (2) 23.1.63	Fresh weight of above-ground parts, as % of control, 3.3.63.	Fresh weight of above-ground parts, as % of control, 26.7.63.
Simazine	1.0	S	2	22	58
"	1.5	S	2	16	20
"	1.5	G	3	35	10
Atrazine	1.0	S	2	29	18
"	1.5	S	<1	2	2
"	1.5	G	1	3	11
Propazine	1.0	S	2	14	19
"	1.5	S	1	7	5
2,4-D + Dalapon (3)		S	5	53	92
Control (4)			5	100	100

(1) S = spray, G = granules; treatment: 23.11.1962
(2) Visual rating, scale from 0 = clean, to 5 = weediest plot at that observation; average of 4 replications.
(3) Treatment: 8.2.1963
(4) Fresh weight of above-ground parts of weeds on control plots: winter weeds = 2920 g/m^2; summer weeds = 214 g/m^2

It must be pointed out that seeds of P. paradoxa may emerge from a depth of 10 to 15 cm and volunteers of cereals from 20 cm. It is perhaps no coincidence that the results show the number of weeds present at the end of the winter in plots treated with the higher dose of the three triazines to be related to their water solubilities, and therefore possibly to the leaching ability of these herbicides in the soil.

The inadequate effect of the dalapon/2,4-D spray on the established weeds was probably because the treatment was delayed until the beginning of February and also because of the relatively short interval (three weeks) between treatment and assessment.

The ploughing and disking in March before planting the sorghum may well have incorporated the herbicides down to 10–15 cm, but the eradication of deep-rooted winter-weeds seems to indicate that the heavy winter rains (about 500 mm in 6 months) had already caused some leaching of the herbicides into the deeper soil layers.

b) Summer weeds. Most weeds which appeared in the experimental field were deep-rooted annuals (Crozophora tinctoria, Ecbalium elaterium, Molucella laevis), typical of dryland. Compared to the weedy control plots, all treatments except the lower dose of simazine gave good control of all weed species present on this experiment, and excellent results were obtained by the higher rate of atrazine and propazine (see table 1). The ranking of herbicides in order of effectiveness against the weeds is the same as for the winter weeds and again may perhaps be correlated to the depth of penetration of the herbicide into the soil.

The results given by granular atrazine and simazine were somewhat erratic compared to equivalent doses of wettable powder; with simazine, the control obtained by granules was worse against winter weeds and better against summer weeds, whereas with atrazine the control was inferior against summer weeds. Lack of uniform distribution at the time of broadcasting may be a partial explanation of these results.

Table 2
Effect of treatments on sorghum

Treatment a.i. kg/ha			Growth of sorghum rating (1) 2.6.63	Yield of sorghum	
				Number heads p. meter row (2)	Total grain yield as % of control (3)
Simazine	1.0	S	4	11	211
"	1.5	S	4	10	191
"	1.5	G	3	10	187
Atrazine	1.0	S	5	12	193
"	1.5	S	4	11	190
"	1.5	G	4	13	215
Propazine	1.0	S	4	11	161
"	1.5	S	5	12	208
2,4-D + Dalapon		S	3	9	139
Control			3	7	100

(1) Visual rating, scale from 0 to 5 = best development at that observation; average of 4 replications
(2) L.S.D. 5% = 3, 1% = 4
(3) Yield of control 100% = 2180 kg/ha
L.S.D. 5% = 51%, 1% = 68%

2) Effect on sorghum

The deleterious effect of the presence of weeds during the winter before sowing the crop is well shown by the difference in yield between the two "controls" (see table 2) which were similarly weedy during the summer, but differed in the extent of the infestation at the end of the winter (see table 1). It seems that at least part of the difference in sorghum yields between controls and triazine treated plots may be attributed to efficient weed control in winter. Although no cultivated control was included in this experiment to permit the direct evaluation of the effects of the triazines on yield, crop growth and yields were generally high and no visually obvious damage was seen on the sorghum (see table 2). A slight depression in growth was observed with the higher dose of simazine but not with atrazine or propazine. The low yield obtained with 1.0 kg/ha propazine seems to be an erratic result, as 1.5 kg/ha gave an excellent yield.

Table 3
Bioassay of herbicidal residues in treated soil - one year after treatment.

Dry weight of above-ground parts of oat plants as % of control				
		Depth of soil sample, cm		Standard with 0.1
Treatment		0-10	10-20	ppmw
Simazine 1.5	S	57	53	6
Atrazine 1.5	S	66	80	9
Propazine 1.5	S	82	91	9
Control		100	100	100

3) Residues

Under dryland conditions, a winter crop, legume or cereal, is usually sown only 3 or 4 months after the sorghum. A herbicide applied to sorghum must therefore be decomposed relatively fast, at least to a level non-toxic to the following crop. The main possible drawback to attempting to use single herbicide application to control weeds in a winter fallow and then in a succeeding summer crop is, that under the climatic conditions of Israel the moisture content of the upper soil layers is sufficient for the decomposition of herbicides for only about six months of the period between application and the sowing of the succeeding crop.

The results of the bioassay one year after the treatment with the higher doses of triazines (see table 3), indicate that active residues were still present in the soil at that time. The incomplete data available from the 20-30 cm soil layer showed an even greater depression of the growth of the oats seedlings. The amount of residual phytotoxicity in the 20 upper cm of the soil ranked: simazine > atrazine > propazine; however, the bioassay standards suggest that the actual concentrations of herbicide in the soil samples were considerably less than 0.1 ppmw.

The wheat sown in the experimental field showed signs of injury only on plots treated with granular formulations; simazine caused severe damage and atrazine slight damage. The apparently greater residual effect of granular simazine than of granular atrazine corroborates the indications of the greenhouse bioassay of the soil samples from plots receiving the wettable powder formulations. It must be stressed that the test plant in the bioassay was oat, which is more sensitive to triazines than wheat. So far, no comparative tests have been done to establish the degree of susceptibility to triazines of other cereals or legume varieties which might be planted after a sorghum summer crop.

CONCLUSION

The experiment shows that a single herbicide application in November at the beginning of the winter rainy season, can effectively control weeds from the start of the winter fallow through crop sowing in the spring, until harvest the following summer. The action of this treatment can be visualised as formation of a long-lasting "poisoned soil layer", toxic to most annual weeds and harmless to the sorghum crop. Under dryland conditions, this chemical technique could replace the cultivation needed for control of weeds in the winter fallow period, for seedbed preparation and for summer weed control; it would be easier and possibly not more expensive than cultivation.

Nevertheless several problems worthy of further investigation may arise when dealing with the practical application of the treatment in different local conditions.

1) The interval between spraying and the beginning of the winter rains

Previous trials indicate that the dissipation of atrazine when exposed on the soil surface, even under the high summer temperatures, is very slight. In the work reported here the herbicides do not appear to have been greatly affected by the 13 day interval between application and the first rain. Nevertheless it is obvious that the herbicide should be applied as near as possible to the beginning of the rains - but their onset is not readily predictable.

2) The spectrum of weeds killed by the triazines

While atrazine and propazine were about equally effective in the trial reported here, the latter is known not to be as effective as atrazine on certain types of weeds (e.g. umbelliferae). Wider scale trials may show propazine not to be as useful as these initial results suggest.

3) The effects of weather on a bare uncultivated soil

On bare soils heavy winter rains may lead to excessive run-off and, on sloping land, to erosion. In summer, a bare dried-out soil tends to crack, increasing loss of moisture.

4) Residue problems

The rate of decomposition of the herbicide in the soil will depend very much on the amount and distribution of the rainfall, both of which are unknown factors at the moment of application. In the absence of accurate long-range weather forecasts to enable the necessary herbicide dose for a particular year to be calculated, the dose for a particular area must be related to average local edaphic and climatic conditions.

Acknowledgement

I should like to acknowledge the helpful criticism and editorial assistance I have received from Mr. S. D. Hocombe in preparing this paper.

A REPORT ON A PROJECT FOR DRIFT FREE AERIAL SPRAYING OF WATER WEEDS

E.C.S. Little and T.O. Robson
A.R.C. Weed Research Organisation, Begbroke, Oxford
and
D.R. Johnstone
Tropical Pesticides Research Unit, Porton Down, Salisbury.

Summary. The Department of Technical Cooperation through the Tropical Pesticides Research Unit, Porton, (T.P.R.U.) supported a project to develop an apparatus for spraying water weeds in ditches accurately from the air without producing spray drift. The project was suggested by the A.R.C. Weed Research Organisation (W.R.O.) as potentially useful both to Britain and many countries overseas. This paper reports the preliminary results of trials in cooperation with the Kent River Board.

The Brantley helicopter operated by British Executive Air Services (B.E.A.S.) of Oxford airport was employed. The spraying apparatus of this aircraft was modified by T.P.R.U. in collaboration with B.E.A.S.

Delivery of spray was from two jets of high volume, high impact, and narrow spray angle. The jets were mounted on the helicopter's skids.

The trials involved testing different jets at 15 ft altitude and 15 mph on typical drainage channels in Kent spraying dalapon at 20 lb a.e./ac in 30 gal water/ac.

Accurate applications of dalapon with very small amounts of drift and no drift damage were obtained. The initial effect on the weeds has been satisfactory. Further trials are planned.

INTRODUCTION

Drainage and irrigation channels soon have their effectiveness impaired by weeds of a wide range of species. The removal of these weeds can be by hand cutting or mechanical extraction or by the spraying of suitable herbicides. Crops are frequently grown adjacent to the channels and these are often susceptible to the herbicides used on the water weeds. Thus water weed spraying has to be done with care to avoid damage to the crops. Spraying from the bank or from a boat can be slow and difficult because of obstacles such as bridges, fences, tributary channels, and by the weeds themselves. Spraying from the air therefore offers a means of avoiding all these obstacles and thus speeding the work. Rapid treatment makes it possible to cover a greater area within the optimum time for spraying with less labour and administrative problems. But aerial spraying is conventionally considered to be risky because of the high speed of operation and the wide swaths usually put down. Both of these factors increase the possibility of herbicide being partly delivered onto the crop. Aerial spraying is also conventionally assumed to demand low volume applications and thus necessarily to use small droplets which are susceptible to drift. In addition the typical aircraft spray rig is based on a wide boom which delivers a swath of about 60 ft width. Only helicopters have the capacity to fly at the slow speeds necessary to follow the sinuous course of many water channels. Thus it was decided that if successful aerial spraying of water channels was to be attempted it was necessary:-

(a) To use a helicopter.
(b) To apply the herbicide as a narrow sharply defined swath.
(c) To use high volumes and large droplets.

Since the work was to be over water there would be ample water available as a diluent. Therefore the project included the study of means whereby the pilot could be supplied with concentrated solution of herbicide along the route of his work and would fill his aircraft with water to dilute the concentrate as necessary at suitable loading points.

After consultation with the aircraft operators, it was decided, to simplify the pilot's task, to spray at a standard height and speed which was chosen at 15 mph and 15 ft altitude. This speed appeared to make it practicable to follow winding water courses accurately and yet to be safe and technically not too difficult for the pilot. The height would be sufficient to avoid most of the obstacles of bushes, bridges, etc. without having to alter height. This height would also be sufficient to contribute to the pilots safety while flying at low speeds.

The reed, Phragmites communis, is a common water weed in Kent and dalapon is approved for use against it on waterways. So it was decided to use dalapon on targets mainly infested with this weed.

METHODS AND MATERIALS

Jets.

The main objective was to deliver onto the target a narrow swath of large droplets with a minimum of fine particles. The faster the droplets travel from the jet the less would be the influence of any cross wind in deflection of the drops from the target. A search through the catalogues of industrial jets suggested that those jets used for washing gravel or similar tasks demanding a high-impact spray appeared to have the desired characteristics. Of this type are the Spraying Systems Ltd. "Flatjet" nozzles and the H.T. Watsons "Strip-Jet" nozzles. Accordingly various sizes of these nozzles were tested on a static rig at T.P.R.U. and on mobile ground rigs, operating at the same speed and height as were to be used in the air, at W.R.O.

Three jets were selected with the characteristics listed in Table 1. T.P.R.U. made detailed measurements of droplet sizes and distribution, and the general results of the ground tests made it appear likely that the jets would prove suitable when used from the air.

Table 1

Characteristics of jets used in aerial trials at 15 ft altitude and 15 mph at 40 lb/in^2.

Jet Type	Size	Maker	Spray Angle	Swath Width	Delivery gal/min.	gal/ac
"Flat"	35100	Spraying Systems Ltd.	35°	7ft	8	33
"Flat"	1560	Spraying Systems Ltd.	15°	4.5ft	5	36
"Strip"	SPJ 4	H.T. Watson Ltd.	-	8ft	6	23

Helicopter.

The Brantley B-2 operated by British Executive Air Services was used. This light helicopter has spray equipment capable of carrying 33 gal and designed for low volume spraying. Considerable modifications to its "plumbing" were therefore necessary and were carried out by T.P.R.U. and B.E.A.S. in cooperation.

Plots.

Typical drainage ditches on the Pett Level near Winchelsea in Kent were made available by the Kent River Board. These ditches were infested with a number of emergent water weeds of which P. communis was predominant. Plots were selected of 0.25 mile length with a width of weeds ranging from 9 to about 15 feet.

For the narrower ditches two "Flat" jets of 1560 size were used. For the wider ditches pairs of "Flat" 35100 or "Strip" SPJ 4 were used. In addition a few acres of reeds on a lake were utilized to make applications with the attitudes of the jets on the skids adjusted so as to give separate swaths with a gap of about 10 feet in between. This jet configuration might be suitable for spraying channels having free water in the middle and bands of weeds on the margins.

Herbicide.

Dalapon was prepared in concentrated solution (4 lb product/gal) and was used diluted sufficiently to give about 20 lb a.e./ac with each type of jet.

Spraying Operations.

A known amount of the appropriate concentration of dalapon solution was filled into the helicopter's tank. The pilot, after some practice runs, then sprayed the plots and was timed on each plot to determine how accurately he had been able to keep to the intended ground speed of 15 mph. After landing the residual spray in the tank was noted. At each take off the pilot could judge the correct operating height by a marker stick standing 15 ft above the weed level in a typical water channel.

Replicate plots were sprayed with each of the 3 types of jets. One run of 1/8 mile with separated jets spraying two bands of the lake weeds was done in the case of the "Flat" 1560 and two with separated "Strip" SPJ 4.

No tests were made of methods of rapid filling of the helicopter.

Manual spraying from the ground of water channels similar to those aerially sprayed was carried out on the same day.

RESULTS

<u>Spraying accuracy</u>.

The pilot was able to maintain the desired height and speed to a satisfactory degree. He was able to follow the bends in the channels accurately even when they were as acute as a right angle turn.

Coverage of the weeds appeared satisfactory. There were instances however when it seemed possible that the downwash of the helicopter may have shaken some of the drops off the leaves.

<u>Drift</u>.

All the jets delivered a small fraction of fine droplets and these could be seen blowing away from the main delivery of the spray as a fine mist. The downwash of the helicopter contributed to this so that a small part of the drift also was delivered upwind. However the amount of spray lost as drift was very small. Complementary physical assessments showed that this would amount to less than 1% of the volume. Thus the risk of damage from drift when using dalapon would appear to be negligible. This was confirmed by the lack of any sign of drift damage outside the target ditches.

<u>Effect on weeds</u>.

A preliminary assessment was carried out 5 weeks after application. A satisfactory top kill of *P. communis*, *Carex* spp. and *Typha* spp. was achieved on all plots. However, although encouraging at this stage, this does not necessarily mean a satisfactory control has been achieved. This can only be assessed from the amount of regrowth which occurs.

<u>Apparent Accuracy of Application</u>.

A very high degree of accuracy was achieved with off-target damage occurring only where the pilot was unable to follow the very frequent tight bends which occurred in one plot or where insufficient allowance was made for the deflection of the swath from the vertical by a cross wind. In the former case half the channel width was unsprayed in two of a series of seven acute bends. As experience is gained in the use of this equipment it may be expected that these errors will be reduced.

The plots sprayed with the jets adjusted to leave a 10 foot unsprayed gap between two 6 foot swaths show a very satisfactory top kill within well defined swaths and no apparent scorch within the unsprayed centre band.

DISCUSSION

The technique of aerial spraying of water weeds by helicopter using narrow-swath high-delivery jets appears promising. Further larger scale trials are needed. The costs of helicopter spraying in terms of actual flying time have not yet been determined from trials under field conditions. It appears possible, from preliminary estimates of flying charges for the Brantley helicopter, that accurate effective sprayings may be achieved at an application cost which compares favourably with that of hand spraying.

Methods of loading in the field need to be worked out. But in typical waterway conditions, where the ground is flat with numerous suitable helicopter landing sites, there seems to be good reason to believe that any difficulties would be overcome.

If this were to prove to be the case aerial application of the type described should give much more rapid treatment of water weeds than current methods and would be possible at an acceptable cost.

With flying skill and reasonable conditions accurate spraying with very little drift could be expected.

Acknowledgements

To Mr. R. Hill of T.P.R.U. and to Mr. R. Stratton of B.E.A.S. for their work on the spraying apparatus without which the trials would not have been possible; to the Kent River Board for permission to undertake the field trials in their area and to Mr. F.N. Midmer, Area Engineer of the Rother Area, Kent River Board for making the local arrangements and providing the necessary labour and materials required.

FLAME CULTIVATION TRIALS

E.J.Creek

Maywick Appliances Ltd., Wickford, Essex.

Summary Several aspects of Flame Cultivation were investigated, these included flame weeding of early and main crop potatoes and sugar beet, de-foliation of potatoes and the control of wild oats.

It was found that flame weeding was successfully accomplished in one application, provided the operation was timed correctly and the soil not disturbed afterwards.

Potato haulm burning was achieved in one application when weed growth was not too great and harvesting delayed for 7 to 10 days. Two applications with a 2 to 3 day interval between flamings allowed the crop to be harvested without delay, and eliminated the majority of weeds.

The control of wild oats in a stubble-field was attempted and appeared to be successful, results will be available later in the year.

INTRODUCTION

Flame Cultivation has been practised in America for several years but one of the factors which prevented its development until recently in this country was the lack of a suitable fuel, cheap enough to make this procedure a commercial proposition to the farmer. With the invention by Maywick Appliances Ltd. of a new patented fuel system* which involves the use of both propane and cheap grade paraffin, an economic method appeared to be available for Flame Cultivation. Hand guns powered by this new system of fuelling were superior to units operated by either paraffin only or existing propane guns.

A tractor-drawn flame cultivator‡ was evolved in 1962 and this proved to be capable of controlling weeds by flaming on a scale hitherto unknown in Gt.Britain. From 1962 to the present time many trials have been carried out. These include flame weeding of potatoes, rhubarb and chrysanthemums, defoliation of potatoes, burning of daffodil trash and the flaming of stubble for control of wild oats.

* "Kerogas" ‡ "Kerovator"

One particular machine has completed three full seasons on a market garden with preparatory work on the beds of radishes, carrots, leeks and red-beet. Onions are flamed at the "crook-stage" with excellent results on weed control. A user who specialises in cos lettuce production flames the beds before planting the crop, reducing the labour and chemical sprays required.

These preliminary investigations gave such encouragement that it was felt worthwhile to carry out a series of trials during 1964, to give comparative costings against existing methods of weed control and to check on the effect of flaming upon crop growth. Since these trials started, it has been decided that they should continue for a further two years in an attempt to produce more detailed results. Four local farmers co-operated by allowing a section of their land to be used as test grounds.

METHODS AND MATERIALS

"Kerogas" is a fuel system employing paraffin as the main fuel and propane (L.P.Gas) for pre-heating of burner coils, as a propellant and for purging the paraffin line at the finish of each operation (See Fig.1).

Flame temperature achieved is in the region of 2,000°F. The "Kerovator" flame cultivator used in this series of experiments has 8 200,000 B.Th.U. "Kerogas" burners, which may be adjusted in the vertical plane from ground level up to 24 in. and provide an effective width of from 5 to 7ft. The paraffin capacity is 24 gal. and consumption of 8 burners totals 10 gal. per hour. Costs are based on an assumed price of paraffin at 1/6d per gal. and propane at 10½d per lb. Estimated propane consumption for a 2.4 hour working operation is 5.3 lb. The whole unit, weighing approximately 5 cwt. is supported by the tractor's hydraulic system.

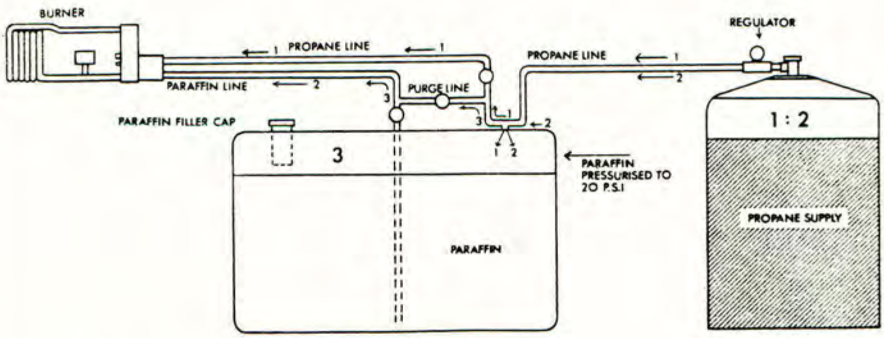


Fig.1. Principle of propane/paraffin burner.

Three main uses of Flame Cultivation were studied and are as follows:-

1. Destruction of seedling weeds.

Flaming for weed control was carried out at various stages in potatoes and sugar beet (Experiments 1-4). For potatoes, the burners were set to cover a width of two and two half baulks, with no attempt made to shield the crop rows from the flame. In sugar beet, an attempt was made to use shields to protect the crop rows, but owing to slack linkage between the flame cultivator and the tractor, it was found impossible to ensure that the shields were in correct alignment for crop protection. The operations were, therefore, accomplished by lateral adjustment of burners so that the flames impinged upon the inter-row strips. A coverage of two and two half inter-row strips was obtained with this arrangement.

2. Potato Haulm destruction.

3. Destruction of wild oat seeds on the soil surface.

For these experiments (5-7) the burners were placed close together, as for pre-emergent weed control in potatoes, but in order to contain and intensify the heat a burner hood 3ft x 6ft was placed around the burners.

RESULTS AND DISCUSSION

1. Destruction of seedling weeds.

Experiment 1.

Potatoes, variety Craig's Royal were planted on 7th May, and one week later, when no potatoes, and few weeds had emerged, an area was flamed at an average speed of $1\frac{3}{4}$ mph. The burners were set 4 in. above the soil and covered two complete baulks. The cost for fuel was 13/2 per acre and the time taken was 45 minutes per acre. One of the latest residual herbicides containing simazine and prometryne was sprayed upon adjacent land. This chemical cost £4.0.0d. per acre and time taken to spray was 5 minutes per acre.

Ten weeks after planting, random samples of weed were weighed from each area. Samples from the flamed area averaged $7oz/ft^2$ and from the sprayed area $6\frac{3}{4}oz/ft^2$. A similar test two weeks later showed an average difference of $\frac{1}{2}oz/ft^2$, in favour of the sprayed section. At this stage fat-hen (Chenopodium album) in the flamed area had become conspicuous, whilst in the sprayed area the predominant weeds were annual nettle (Urtica urens) and volunteer barley.

Samples of the crop taken from both areas at harvest time indicated no obvious difference in yield or quality. It is believed that a greater impact upon the weed population would have been made had the flaming been delayed until more weed had emerged. A burner hood as used in in experiments 5-7 might also have improved results.

The economics of this operation were in favour of flaming, but the inconvenience of utilising man and tractor for 45 minutes compared to 5 minutes required for spraying must be remembered. One advantage of flaming over spraying is that it can be carried out under adverse weather conditions. If a tractor can be used on the land then it can be flamed. Rain and wind have little or no effect upon results.

Experiment 2.

On 16th June 1964 a flame weeding experiment took place on King Edward and Majestic main crop potatoes. The crop had been planted 15th May, and were approximately 3 in. high when treated.

The burners were adjusted to a height of 4 in. from the ground. Forward speeds ranging from ½ mph to 2 mph were used on pre-determined strips, control rows intervened. A very good kill of weeds was observed but severe damage to crop foliage was caused in rows where the lower speeds were employed. Some plants in the rows subjected to ½ mph travel possessed only a bare stalk following this operation. However, a remarkable recovery was made and four weeks later these were indistinguishable from control rows.

Equal samples of both varieties were checked for weight and shape and some from both flamed and control areas have been stored to assess keeping quality. There was no detrimental effect arising from the flaming upon the yield or shape of the crop, samples subjected to the higher speed treatment, appeared to gain the greatest benefit.

Necessary drainage work was carried out in some furrows shortly after flaming and where the soil was disturbed, weed population two weeks later showed an increase of almost 70% over undisturbed furrows.

Flaming was attempted on twenty short rows when the crop was 15 in. high, but abandoned after 8 rows had been treated. Damage caused to foliage and stalks by tractor wheels was likely to encourage blight. The latter part of this experiment highlights a drawback to inter-row treatment of potatoes. The use of narrow wheels on the tractor would minimise possible damage to the crop but a wider coverage per tractor run is also required.

The importance of timing was also emphasised by the last operation. Large weeds in the short rows were checked, but not killed by this single application.

Experiment 3

Flame weeding was carried out on sugar beet, variety Triplex "M" which had been planted on 1st May 1964.

Against a comparison of mechanical plus manual cultivation, one ¼ acre was flamed on 21st May at a speed of ¾ mph. One row was accidentally impinged upon by the burners and immediately wilted. Ten days later the affected plants had recovered. An excellent kill of weeds was observed.

Close observation, especially after singling, was kept on this section. Owing to dry weather conditions it was found unnecessary to flame again. Later checks proved there to be no difference in weed control between this and the cultivated area, which had two operations mechanical cultivation at the same time as the flaming and manual hoeing, a week after singling.

Fuel cost for flaming was £1.15s per acre and time taken was 2 hours per acre. Mechanical and manual hoeing time taken was 10 hours per acre, so this particular experiment showed a very definite advantage for flaming, on time taken to deal with the weeds.

Samples taken under the supervision of the British Sugar Corporation Limited, were weighed and an analysis provided on sugar content. These showed that the flamed beet had not been adversely affected and there was no conclusive difference between the two sample batches.

Experiment 4.

A further ¼ acre of Triplex "M" sugar beet, planted 12th May 1964 was flamed on 25th May, when the crop was at the two-true-leaf stage. Tractor speeds ranging from ½ to 1½ mph were used on various strips with control rows at intervals. Although burner adjustments were made to the flame cultivator, as described under "Methods" foliage damage was still considerable at the lower tractor speeds. Some plants had only the "crown" at ground level left unaffected, but all recovered within 10 to 14 days. Variation in weed kill between strips flamed at different speeds was insignificant.

After singling, followed by rain, weeds germinated rapidly and weed growth was abundant. A post-singling flaming was therefore carried out on 7th July. Speed of travel was 1⅓ mph (1 acre per hour) giving a fuel cost of 17/6d per acre. Weed kill in this instance was only 28.5%, but this poor result is explained by the fact that flaming had been delayed for more than a week for lack of a tractor, and over 70% of the weeds were by then over 2½ in. high, or beyond the 4-leaf stage, which is regarded as the limit for selective flaming.

The leaves of the beet were discoloured and wilted by this operation but all produced new foliage and caught up with the control rows within 14 days. Samples were weighed and analysed by the British Sugar Corporation Limited, whose report showed no apparent difference between flamed and hoed beet.

It is expected that the advantage of flaming would be most pronounced during a season when weeds apparently thrive upon mechanical or hand hoeing and when disturbance of the soil enhances new germinations. The rapid growth of weeds following singling in this experiment and the inability to flame them immediately, points out the value of correct timing for thorough weed control. Provided this condition is met there is an obvious time saving element in flaming compared to ordinary cultivation and the cost of fuel does not outweigh this advantage.

2. Destruction of potato haulm

Experiment 5.

The flame cultivator was used to defoliate secon early potatoes on 14th August. The burners were set a height of 12 in. from the ground. A forward speed of ½ mph was employed but owing to adverse weather conditions and a heavy infestation of weeds a second application was needed. This was carried out on 29th August 1964. A burner hood measuring 6ft wide by 3ft long was fitted to the machine and a forward speed of 1½ mph was used. The long interval between first and second applications was caused by the tractor being unavailable at an earlier date.

The haulm was destroyed but a certain amount of weed stalk (mainly C.Album) was still evident. However, this did not impede harvesting of the crop. The total time taken for the two operations was 3½ hours per acre and the total fuel cost per acre was £2.14.7d.

The use of the burner hood was felt to be advantageous, giving a greater concentration of heat in the required area. The advantage over the other method of haulm destruction used on this farm, i.e. forage harvester, is the minimal disease risk compared with mechanical cutting of stalks and foliage.

Experiment 6.

Main crop potatoes, were treated on 1st October, 1964 using the flame cultivator plus burner hood. Burners were set as in experiment 5 at a height of 12 in. and a speed of 1 mph used. Within 2 hours the haulm had discoloured and wilted. Two days later it was obvious that no further treatment would be needed and that harvesting could be effected seven days following the flaming.

Dry foliage and good weed control assisted this operation which has taken 64 minutes per acre to perform and cost £1.3s 4d per acre for fuel. Compared with the normal method of defoliation used on this farm (the contractor's all-in price is £4.10s 0d per acre for sulphuric acid spraying), flaming has an economic advantage.

3. Destruction of wild oat seeds on the soil surface.

Experiment 7.

The destruction of wild oat (Avena fatua) seeds in a stubble field was attempted with the flame cultivator on 24/25th August 1964. The burners (with hood) were set to give a 6ft coverage and their distance from the ground was adjusted to approximately 6 in. A speed of ⅗ mph was employed, representing a fuel cost of 35/-d per acre and a coverage rate of ½ acre per hour.

Samples taken from the surface and various depths have been submitted to Rothamsted Experimental Station for analysis but results will not be known until later this year.

It is thought that to cover a field systematically with a concentrated form of heat would, over a period of years, bring under control various weeds such as A.fatua. Expectations are that in addition to seeds destroyed a number would be prematurely germinated by the intense heat and would die with subsequent cultivations. Bad weather conditions experienced at harvest time would not unduly affect results. Further flame treatment in the spring possibly as a pre-emergent treatment, could be adopted in heavily infested areas.

Advantages over random firing of straw or stubble are (a) a more complete coverage of the infested area, (b) a greater flame temperature achieved, therefore a more effective control, and (c) the ability to flame despite adverse weather conditions.

Improvements to equipment and techniques expected for the future, should bring increased advantages for Flame Cultivation. Great interest created by these trials, extra facilities and outside co-operation promised, will make possible a comprehensive method of test plot allocation and result checking in 1965. Acceptable statistics will be available from work on such crops as sugar-beet, potatoes, onions, red-beet and cabbage at the end of 1965.

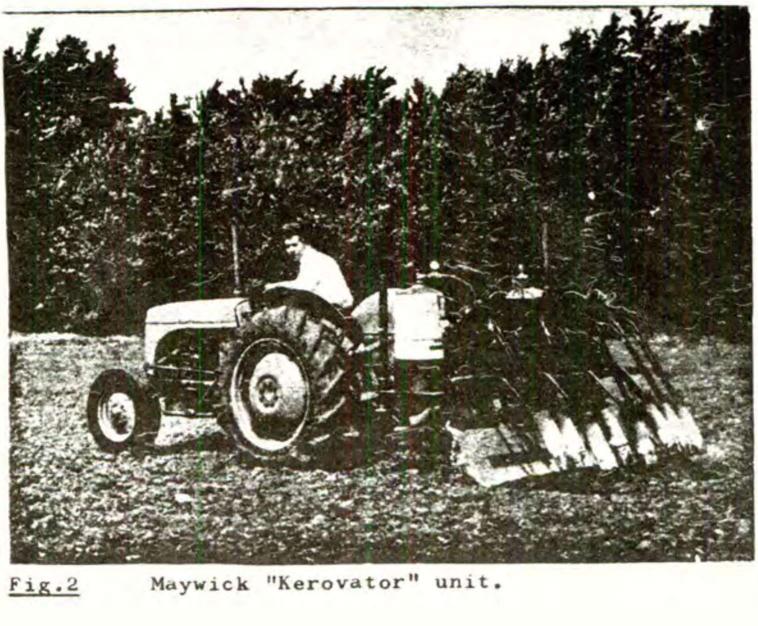


Fig.2 Maywick "Kerovator" unit.

THE USE OF HERBICIDES ON NURSERY ROOTSTOCKS

R.I.C. Holloway
East Malling Research Station, Kent.

Summary Trials were carried out using simazine, diuron and 2,6-dichlorothiobenzamide on bedded and lined out rootstocks of apple, plum, quince and cherry and also on cuttings of apple and plum. The most promising treatment for general use on fruit tree rootstocks was simazine at 1 lb/ac.

The fruit tree nursery is intensively planted and of high value per acre. Traditionally a high standard of weed control has been maintained involving a large amount of hand work and slow careful work with machinery. Thus the use of herbicides is economically desirable but the avoidance of harmful effects is of the utmost importance.

In 1963 three herbicides were tested on three groups of rootstocks:-

1. First grade rooted layers of the apple rootstocks M.VII and MM.104, the plum stocks Brompton and St. Julien A, the cherry stock F12/1 and Quince A, commonly used for pears, lined out as for budding.
2. Lower grades of the above stocks bedded out to increase in size and rooting before being suitable for budding.
3. Hardwood cuttings of M.VII, MM.104, Brompton and St. Julien A.

The treatments were 2,6-dichlorothiobenzamide at 2 and 4 lb/ac, diuron at 1 lb/ac and simazine at 0.5, 1 and 2 lb/ac, all applied in early April, two weeks after planting. All plots were hoed just before the treatments were applied, and the control plots were hoed four times more during the growing season, at 4 to 6 week intervals, when the height of the weed cover reached about 2in.

Leaf injury and weed cover were assessed through the season and detailed records of extension growth, stem diameter, plant weight and root weight were made when the plants were lifted the following winter. In many instances no leaf injury was found. Only where 40-50 per cent of the plants were affected did the damage extend beyond the lower three leaves of the current season's growth. The percentage of plants with leaf injury is shown in Table 1.

There were no differences in leaf injury between the two apple rootstocks and so these are not shown separately, but it can be seen that St. Julien A was more sensitive than Brompton. Leaf injury was greater on the smaller plants, except on the quinces. (The quinces were anomalous probably because the lined out stocks had been killed to within eight inches of the ground in the severe winter before planting, leaving a large root system to supply an initially very small shoot system, whereas only the tips of the bedded stocks had been killed). Simazine at 0.5 and 1 lb/ac and 2,6-dichlorothiobenzamide at 2 lb/ac caused no damage. The apples showed fewest leaf symptoms, being injured only by 2,6-dichlorothiobenzamide.

Table 1

Percentage of plants with leaf injury

		Simazine			Diuron	2,6-dichloro-thiobenzamide	
		0.5	1	2	1	2	4 lb/ac
Apple	- lined	0	0	0	0	0	0
	bedded	0	0	0	0	0	<5
	cuttings	0	0	0	0	0	50
St. Julien	- lined	0	0	<5	0	0	10
	bedded	0	0	5	10	0	10
	cuttings	0	0	10	10	0	50
Brompton	- lined	0	0	0	0	0	5
	bedded	0	0	<5	<5	0	5
	cuttings	0	0	<5	<5	0	40
Cherry	- lined	0	0	<5	5	0	<5
	bedded	0	0	<5	5	0	50
Quince	- lined	0	<5	10	5	0	5
	bedded	0	0	0	0	0	0

Despite the leaf injury from some treatments, when the plants were lifted the herbicide treatments all gave plants either equal to or significantly larger than the controls, but never smaller. The control plants may have been checked by the cover of small weeds that developed between hoeings during the early part of the summer.

Some of the herbicide treatments produced larger plants than others. Simazine was outstanding in that it was often the only treatment to give plants significantly larger than control, the other treatments lying between these two. Only on apple cuttings did diuron and 2,6-dichlorothiobenzamide give better results than simazine, but the higher rate of 2,6-dichlorothiobenzamide gave less growth than the lower rate on apple cuttings and lined out MM.104. All results with simazine were examined for any variation in growth proportional to the rate of simazine, but the only clear difference was on lined out M.VII where, despite the absence of leaf injury, the highest rate gave least growth.

By August the 2 lb/ac 2,6-dichlorothiobenzamide plots required hoeing, as did the 4 lb/ac plots and the 0.5 lb/ac simazine plots in September. When the plants were lifted in the following March, the 1 lb/ac diuron and the 2 lb/ac simazine plots were virtually weed free; there was then approximately ten per cent weed cover on the 1 lb/ac simazine plots and ninety per cent cover on the controls.

Considering all the results together, simazine at 1 lb/ac appears to be the most promising treatment for general use on nursery stocks. The use of diuron at rates lower than 1 lb/ac should be investigated as a possible alternative. Attention must be drawn to the fact that the experiments noted here took place on one soil type (a fine sandy loam) in one season and also that any effects on the take and growth of grafts were not studied.