DECLARATION

I hereby declare that the whole of the work now submitted as a thesis for the Master of Science degree of Ahmadu Bello University is the result of my own investigation except where reference is made to published literature and where assistance is acknowledged.



Candidate

STUDIES IN THE CHEMICAL CONTROL OF WEEDS NOT READILY CONTROLLED BY CULTIVATION

"Striga hermontheca"

by

James Ogborn

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striga is not only a major economic evil but also has serious social disadvantages. In some heavily infected areas the well manured land close to the villages cannot effectively produce grain. Production then has to be done at inconvenient distances from the village. The writer has personally observed many examples of this while touring in the less developed parts of the country. At one village near Dengi in Plateau province, the village head informed the writer that the village site had been moved twice in five years as a consequence of striga infestation. It was now no longer possible to grow the most palatable and productive sorghum varieties because they were too susceptible to striga attack. The uncultivated land in the area was so heavily infested that sorghum crops planted on newly cleared land were immediately heavily attacked and many acres abandoned before harvest.

At Laukoviri in Adamawa province it was stated that sorghum crops were usually planted on the hill tops instead of in the more fertile valleys. The writer expected to be told that this was to avoid areas infested with Imperata cylindrica but the

emphatic answer was that 'it reduced striga attack'. There was no possibility that the informants could have known about the writer's research interests. These two communities do not have such well developed systems of intercropping as the long established Hausa farmers in areas like Samaru. Here the cultivators generally keep the striga infestation at tolerable levels by one or two hand pullings of the emerged parasite each season. The losses of potential grain yield which occur in intercropped sorghum have not been estimated in this area but the extension services report that farmers consider that serious losses do occur.

At best, striga appears to be an omnipresent nuisance to the subsistence farmer growing mixed crops and requires continuous effort to keep it in check. At worst it is undoubtedly an intolerable and demoralising economic and social evil which can disrupt the lives of whole communities of subsistence farmers.

The practice of growing a high proportion of the sorghum in mixture with other crops undoubtedly aggravates the striga problem. These mixed cropping

areas occupy the most heavily manured land near villages. They are usually cropped every year without rotation and this enables the striga to persist and set seed under all except the most stringent hand weeding regimes.

Part of the losses are impossible to prevent by hand cultivation because they occur before the striga emerges. The striga would be vulnerable to a selective soil acting herbicide before it emerged and a fundamental advance would be achieved if a suitable material were discovered.

Up to the present there has been little published work on the herbicidal control of S. hermontheca with any herbicide except 2,4-D. The investigation reported here was therefore mainly concerned with screening a wide range of different types of herbicide for selective activity against S. hermontheca parasitising sorghum.

S. hermontheca was given the common name 'giant witchweed' by Timson (1936a) to distinguish it from S. asiatica which is commonly called 'witchweed' in southern Africa and the United States of America.

In this text, S. hermontheca is commonly referred to as 'striga' and the name 'witchweed' is used only for S. asiatica.

To avoid unnecessary repetition of the complicated dimension 'lb. of active ingredient per acre' this is denoted by the symbol '≠' in the following text.

CHAPTER 2

LITERATURE REVIEW

(a) Species description and distribution

i. Historical

Chevalier (1929) states that S. hermontheca was originally described as Buchnera hermontheca by Delile, who found it growing in sorghum fields at Erment in Upper Egypt. The species was named 'hermontheca' after the earlier name of the site, which was 'Hermonthis'. Striga senegalensis Benth (1846) was described as probably a small-flowered form of S. hermontheca (Hemsley and Skan, 1906). The distinction was no longer recognised by Hepper (1963). See Appendix I for description of S. hermontheca at Samaru. One of the other economically important species Striga asiatica Linn. O. Kuntze is also present in northern Nigeria but is not abundant (Williams, 1958).

ii. Geographical distribution

The records of the reported occurrence of the species Striga hermontheca are given in Appendix 2. The species is essentially tropical in distribution and confined to the African sub-continent, except for

Madagascar (Hepper, 1963) and a single reported collection from Arabia (Helmsley and Skan, 1906).

The author of this review saw a Striga sp. which was almost certainly hermontheca parasitising 'durra' type sorghum at Giar Research Farm in the Abyan area of Southern Arabia about 1956-58. As historically there has always been a regular interchange of sorghum seed with similar areas in Eritrea and the Sudan, it seems likely that the parasite was occasionally imported with the cereal seed. There are apparently no known areas of Southern Arabia where the parasite regularly causes measurable crop losses, probably because nearly all the cropped area is heavily irrigated.

Mozambique and Rhodesia are the most southerly areas from which the species has been reported. There is only one modern reference to Striga hermontheca in Mozambique but this may simply be due to lack of scientific activity in the area. There is no doubt that the species occurred at the same latitude in Rhodesia (Timson, 1936a) and it may therefore be assumed that it can be found whenever the environment

is suitable in all parts of central and east Africa to the north of this latitude. Tarr (1962) observed that there seems to be no reason why it should not occur in Asia.

iii. Occurrence in Nigeria

S. hermontheca is present in most cereal crops in northern Nigeria. This probably explains why there are comparatively few recent reports of its occurrence. Botanists may have assumed that such a common weed did not need to be reported. It is apparently unknown in the Forest zone but the present author has observed it in the Southern and Northern Guinea Savannas, the Sudan Savanna, and the Sahel zones. It is probably less abundant in the maize growing areas of the Southern Guinea Zone but no quantitative observations have been recorded.

(b) Economic importance

i. Research

The economic importance of the losses caused by Striga spp. was first described by Fuller (1900) with reference to Striga asiatica attacking cereals in Natal, S. Africa. Subsequently, Pearson (1913) drew

attention to the damage done by uncontrolled witch-weed attacks and initiated research into the control of S. asiatica in South Africa and Rhodesia. A further intensive research programme was started when S. asiatica was found in North Carolina, U.S.A., in 1956 (Garris and Wells, 1956). By comparison, comparatively little work has been done on Striga hermonthecа. Wilson-Jones (1953a) suggested that this was mainly because there were more farmers of European descent in the S. asiatica areas. Only three papers by Macdonald (1928, 1929a, and 1929b) had been published in East Africa before Doughty (1940) started detailed studies on the species. Andrews (1945) published the first specialised study of S. hermonthecа in the Sudan.

ii. Yield losses caused by striga

Doughty (1942) described crop losses in East Africa and more recently Dogget (1965) has measured them in this area. A loss of about 500 lb. of sorghum grain per acre was attributed to striga attack in one example. In the Sudan both Last (1960) and Wilson-Jones (1956) performed experiments which indicated that striga damage was greatest at low soil

fertility and could be partly alleviated by manuring. This was also the opinion of Porteres (1948). Basinski (1955) demonstrated that this was not always the case and that some of the 'low fertility' of old arable areas of the Sudan was due to striga infestation.

Some of the most detailed work on crop losses has been done at Samaru and Yandev (Northern Nigeria). Gisborne (1953) stated that he knew of no statistically significant loss of yield caused by striga attack, but Butler (1954) showed that hand-pulling of striga at Yandev increased the grain yield highly significantly from 76 lb. to 293 lb. of grain per acre. Watson (1958) reported that after five years of hand-pulling at Samaru, the grain yield was significantly increased from 455 lb. to 554 lb. per acre, while the striga count was reduced from 8,111 to 2,459 per acre. Clearly at this level of striga emergence, the effect on yield was not large. At Yandev, where the natural level of infestation produced an emerged striga population of 111, 750 per acre in 1954, the yield of sorghum grain was increased from 452 lb. per

acre to 751 lb. by hand-pulling the striga. The effect of three years of hand-pulling was to reduce the emerged striga population to 26,300.

Even when striga is removed by hand-pulling, some damage is done to the sorghum before the striga emerges. These measured responses to hand-pulling are therefore, minimal estimates of the loss of potential yield caused by striga attack.

It would appear that the effect of striga on yield depends on the interactions of three factors:- the susceptibility of the host to attack; the level of striga infestation; and the fertility of the soil.

(c) Life history of the Striga spp.

i. Recognition of parasitism

The classical studies by Saunders (1933) authoritatively described the mode of parasitism of Striga asiatica. Williams (1958) reviewed the work on other striga species and concluded that they were all obligate parasites on the roots of higher plants, with the possible exception of S. euphrasiodes and S. densiflora, about which there is some divergence of opinion. He reported as an original observation

that in Nigeria, S. hermontheca could survive for some weeks after the host plants had died and quoted reports that S. asiatica (Lewin, 1932) and S. euphrasiodes (Sharma et al, 1954) could do the same. Williams also mentioned that it was often very difficult to detect parasitic connections between witchweeds and their hosts in the field so that reports of living specimens of Striga spp. growing independently of their hosts should always be viewed with suspicion.

ii. Root exudate necessary for germination

Saunders (1933) quotes Fuller (1900) as being the first to notice that witchweed seed would not germinate unless in close proximity to a suitable host root. Saunders (1933) showed that maize roots exuded a substance which had to be present before witchweed would germinate. Phaseolus vulgaris 'which was not a host' apparently did not exude a similar substance but later work by Rose and Lochrie (1941) showed that Phaseolus vulgaris root exudate could bring about the germination of Striga asiatica. The discrepancy between these two findings can be attributed either to a difference in technique or, possibly, to the use of different varieties of P. vulgaris.

A list of plants which produce root exudates which could cause S. hermontheca to germinate was published by USDA (1957). A number of these plants are grown in northern Nigeria and these have been listed in Appendix 2, together with the status of the plant as a host.

The Gramineae, including many of the common weed grasses found in northern Nigeria, are all reported to be full hosts on which the Striga hermontheca is capable of maturing fertile seed. Dolichos lab-lab is the only non-gramineous host which has been definitely observed to support fertile seed production by the striga and Andrews (1945) observed that the striga flower heads were small and stunted. He also observed that Arachis hypogea and Glycine max were reduced in vigour by Striga hermontheca attack. This indicated that they were definitely parasitised and that under favourable conditions the parasite might be able to produce aerial stems and set seeds while parasitising these species.

iii. Seed formed from immature ovaries

Andrews (1945) found that the green ovaries in

the flowering S. hermontheca plant produced ripe seeds if they were left to lie on the ground.

iv. Effect of age of Striga hermontheca seed on germination

Doughty (1942) found that the germination of S. hermontheca seed increased more than fourfold when stored in a dry air-tight tube for six months as compared with fresh seed. Andrews (1945) found that S. hermontheca seed could remain viable for at least five years in the soil of the Gezira Research Farm. Vallance (1950) found that peak germination capacity increased from 37 per cent at one year old, up to 78 per cent at six years. Williams (1958) incorrectly quoted two years as the age of maximum germination. This is actually the age of maximum germination found by Vallance (1950) on re-wetted seed following a period of wet dormancy. Vallance (1950) concluded that the main factor responsible for variations in germination was the duration of the period of dry seed storage.

v. The effect of pH on the germination of Striga spp.

Pearson (1913) found that S. asiatica seeds germinated more readily in an acid than in a neutral

medium. They did not germinate readily in the presence of a free alkali such as ammonia. Saunders (1933) observed no effect when the pH of the solutions moistening the germinating seed was varied from 6.0 - 8.0. Doughty (1942) referred to the possibility that a pH of 4.5 in an experimental soil might have had some influence on the germination of the parasite but did not report any experiments to confirm this.

vi. Effect of temperature on the germination of Striga spp.

The optimum temperature for the germination of S. asiatica is 30°C (Saunders, 1933). Germination was completely inhibited by temperatures below 15°C and above 40°C. A little germination occurred at 20°C. Doughty (1954) attributed the limited germination of S. hermontheca in pots in greenhouses at Eldoret, Kenya, to diurnal temperature fluctuations. Kust (1954) showed that pre-treatment with water at 22°C gave better germination than at 12°C or 27°C.

vii. Effect of moisture on germination

Vallance (1950) showed that if pre-treatment with water only was prolonged, Striga hermontheca seeds went into a condition described as wet dormancy.

The seeds were incapable of germinating until they had been dried. They could then be made to germinate by re-applying the wetting treatment, followed by treatment with germination stimulant. This is the probable explanation of the common observation that striga attack is least under very wet conditions. Andrews (1945) observed that striga attack was greatest in a lightly irrigated part of a sorghum field. A field experiment showed that in the lightly irrigated treatment the intensity of the striga attack increased more than in the heavily irrigated treatment. In the Sudan, Wilson-Jones (1953c) recommended heavy watering for irrigated sorghum because 'witchweed cannot survive waterlogging'.

A season of light rainfall is usually one of heavy attack and vice versa. These observations may not be solely due to the effect of moisture on germination (see viii below). Kust (1966) leached seed of S. asiatica for twenty four hours and removed a germination inhibitor. Germination after leaching was dependent upon the relative concentrations of inhibitor and stimulant in solution. It is probable that the proportion of the stimulant in proximity to

a host root would be greatest in a dry soil.

viii. The underground development of Striga hermontheca seedlings

Doughty (1942) germinated S. hermontheca seed in test tubes in the presence of sorghum and maize seeds. Striga seeds were observed to germinate seven days after the host seeds were sown and two days after the host roots were seen close to the seed. A drawing showed five out of eleven seedlings attached to a host root and Doughty commented that the remainder showed no tendency to grow in the direction of the host root. This lack of directive stimulus was noted in most tubes containing germinating striga seeds in other experiments. Saunders (1933) also observed this phenomenon in S. asiatica cultures when excess water was present. Andrews (1945) observed that striga seeds only germinated at 1 cm or less from a host root and germination occurred three days after stimulation by a host root. The striga radicle did not necessarily grow in the direction of the stimulating root. On making contact with a host root, the radicle formed a swelling at the junction, the intervening tissue between the host root and parasite

root dissolved and the conducting tissue of both host and parasite became united. The striga seedling did not begin to develop its plumule until the union with the host had been completed. The highest level of parasitisation (600 parasites per sorghum plant) was found five weeks after sowing. A reduction occurred in the six and seventh week, which was tentatively attributed to shedding of striga seedlings during host root thickening.

Agabawi and Younis (1965a) sowed seeds at different depths in pots. The proportion of germinated striga producing aerial shoots fell from 69 per cent at the surface to 2 per cent at 15 cm. No emergences occurred from greater depths. Dry matter yields of sorghum were least when the striga emerged from depths of 0 and 5 cm.

Okonkwo (1966) was the first to grow Striga hermontheca to maturity in vitro. It was necessary to germinate the striga seed with aqueous sorghum root extract. He concluded that the parasite seedling depended on its host only for water, mineral salts and sugars and not for more elaborate substances.

Wilson-Jones (1955) reported the existence of

physiological strains of Striga hermontheca adapted to parasitising Sorghum vulgare and Pennisetum typhoides respectively. The resistance was attributed to a restriction of transfer of nutrients from the host. There was no restriction in the production of germination stimulant.

ix. Growth of Striga hermontheca above ground

Andrews (1945) found in the Gezira Research Farm that the earlier the sowing date of sorghum between June and October, the greater the striga attack. Striga emergence commenced at the end of the first month after sowing, reached maximum flowering toward the end of the second month and began to slow down in the third. An average Striga hermontheca plant produced about sixty capsules each containing about seven hundred seeds. About seventeen times as many parasites failed to emerge above ground for every parasite which successfully emerged. Chevalier (1929) observed that S. hermontheca was a light-loving plant which could make good growth in areas of poor host stand. Heinricher (1913) noted the extreme variability in size of this species, having observed a specimen of 20 cm height and another of 60 cm height. Wilson-Jones (1952) observed that sorghum seed sowed in

the field on June 15th had a first emergence of striga on July 14th. Wilson-Jones (1953c) stated that striga flowered two weeks after emergence and also stated that there were no known instances of S. hermontheca or S. asiatica perennating even when the normally annual hosts had been kept alive beyond their normal span. In an abstract of a Hungarian publication, Agabawi and Younis (1965b) observed that striga plants parasiting adventitious sorghum roots at the soil surface remained small (presumably in contrast to plants originating lower in the soil).

No work appears to have been done on the effect of climate on rates of growth or maturation of S. hermontheca but Gisborne (1953) attributed a reduction in the seed setting of striga in 1948 at Samaru to heavy shading by the crop.

(d) The germination stimulant

i. Identification

Brown et al (1949) found that the concentrated exudate from Sorghum vulgare seedlings contained carbohydrates and particularly pentoses, although aldopentoses appeared to be absent. D-fructose; D-fructose-1, 6-diphosphate and L-sorbose weakly

stimulated S. hermontheca seed to germinate. The most powerful stimulation was given by D-oxy-o-ketose. Fresh preparations of the concentrated exudate and of D-oxy-o-ketose were also similar in the important respect that when stored at 5-45°C, the activities of both disappeared completely within 72 hours and that they were both completely inactivated by heating at 60°C for 60 minutes. Brown et al (1952) demonstrated that the stimulant properties of crude preparations of S. hermontheca germination factor may be due to a complex of substances. Brown et al suggested that the parasite seed was supplied from actively growing host roots with a hormone which was normally required in germination but which was not synthesised by the seed. The natural stimulant was probably at least similar to D-oxy-o-ketose. Both the natural stimulant and D-oxy-o-ketose stimulated extending pea root segments to increase in volume. Brown et al (1950) concluded that the stimulant was a generalised root extension stimulator, which promoted the germination of striga seeds. Lansdown (1956) isolated the crude stimulation factor into four components, none of which had any stimulatory activity by themselves.

Sunderland (1960) found that germination of S. hermontheca was promoted by a water-soluble constituent (which he termed 'MS') of maize root exudates. This was suggested as a precursor to another soluble germination stimulant for Orobanche sp., which is also found in maize root exudates. The synergistic effect of small quantities of linseed root diffusate solution added to 'MS' suggested that linseed, sorghum and maize may all produce a similar complex of stimulants, differing only in the particular balance of the constituents.

There does not appear to be any more recent work on the identification of the Striga hermontheca stimulant but work on Striga asiatica germination stimulant has continued at North Carolina (see below).

ii. Isolation from root exudates

Brown, Robinson and co-workers did not succeed in isolating the S. hermontheca stimulant in pure state /Latest references:- Brown, Robinson and Johnson (1950)_7. Worsham et al (1964) absorbed the stimulant from corn (Zea mays L.) roots on activated charcoal and partially purified it by chromatography. A molecular weight of slightly over 100 was estimated by a diffusion method.

Reactions with classification reagents indicated that the stimulant possessed one or more hydroxyl groups and possibly an ester or lactose bond. Results with Ehrlich and Salkonski reagents were characteristic of indole compounds but none of the commonly occurring indoles were active in promoting germination. The stimulant may be similar to coumarin or related compounds.

Egley (1965) showed that the chromatographic analysis of the S. asiatica stimulants exuded from the roots of maize, cotton and Coleus sp. indicated that the exudates had similar reference values. The exudates. produced by the three species were inactivated when held at pH 9 at 50°C for an hour but not at pH 6.5 for three hours. The stimulants were probably similar.

Egley and Cook (1966) reported the isolation of a crystalline germination stimulant (trivial name strigol) for S. asiatica from cotton root exudates. The formula was $C_{19}H_{22}O_6$. Although apparently different from known plant hormones, the stimulant was active at concentrations at which hormones produced their effects causing germination at less than 10^{-5} p.p.m. A non-crystalline substance (B) was also found to be active.

as a germination stimulant. The molecular formula was identical with that of gibberellic acid which is inactive.

iii. Other chemicals stimulating germination of S. hermontheca or S. asiatica

It is probable that seed of both species reacted similarly to natural germination stimulant (Doughty, 1942) and it is probable therefore that a chemical which stimulates germination in one species will do so in the other. Table 1 lists the activities reported by various authors.

Table 1: Chemicals stimulating germination of Striga spp.

Chemical	Striga species stimulated	Authority
Allyl-2-thiourea	asiatica	Shaw et al (1962)
Sodium diethyl dithiocarbamate	"	"
L.-methionine	"	"
n-propyldi-n-propylthiol carbamate	"	"
6-phenyl purines	"	"
6-benzyl purines	"	"
6-furfuryl purines	"	"
6-methoxy-7-hydroxy-coumarin	"	"
4-hydroxycoumarin	"	"
Sarveroside	"	Cook et al (1966)
Thiourea	"	Brown & Edwards (1945)

Table 1 (contd.)

Chemical	Striga species stimulated	Authority
D-xyloketose	hermontheca	Brown et al (1949)
D-fructose	"	"
D-fructose-1:-diphosphate	"	"
L-sorbose	"	"

iv. The existence of germination inhibitors in resistant sorghum varieties and striga seeds

Williams (1959a) showed that the resistant sorghum variety Framida produced a substance which inhibited the germination of striga seeds and also produced less 'germination stimulant' than a susceptible variety 'Light Mori'. At least two inhibitors were also present in Striga asiatica. These prevented cell extension of germinated seedlings of S. asiatica. In a later paper (Williams, 1959b) one of these inhibitors was reported to inhibit cell extension of Striga hermontheca seedlings also. Prolonged periods in the inhibitory solution resulted in loss of polarity by the seedlings. The inhibitor was thought to be an aliphatic acid.

v. Chemotrophic factors affecting striga seedling growth

When S. asiatica seedlings were grown in vitro (Williams, 1960), the radicles were observed to be curved.

The curvature was shown to be associated with an inhibition of cell extension on one side of the radicle. The factor causing the inhibition was shown to be similar to, but distinct from, indole acetic acid (IAA).

Kinetin at 1 p.p.m. or blue light were shown to have strong morphogenic effects on S. asiatica seedlings grown in the vicinity of a host plant. It was suggested that one component in germination complex of S. asiatica might be a kinetin-like substance which both induced germination of striga seeds and induced morphogenic changes in the seedlings (Williams, 1961a).

In a second paper in 1961 Williams reported that positive chemotropism was not complete in agar and attributed this to variation in the orientation of the S. asiatica seedlings relative to the host roots (Williams, 1961b).

(e) Methods of Control

i. Mechanical destruction by selective handweeding

This method, which consists of removing and destroying the parasite by hand-pulling or hoeing without destroying the host crop, was the earliest control measure advocated for control of Striga asiatica.

In West Africa, Chevalier (1929) recommended that all plants of Striga hermontheca should be pulled up before they seeded not only in cultivated fields but also in recently fallowed land, where it is parasitic on wild grasses.

Two long term experiments in Nigeria at Samaru and Yandev were reported on at intervals by various authors (Gisborne, 1953), (Butler, 1953-5), (Watson, 1956-8). The results for five seasons at Samaru showed that hand-pulling did not significantly affect yields at low levels of infestation (less than 10,000 emerged striga plants per acre). In the majority of the results from Samaru, the number of striga plants emerging on the 'hand-pulling' treatment was higher than on the 'not hand-pulled' treatments. The data for six years of the experiments at Yandev showed that hand pulling of striga plants at high levels of infestation (50,000 - 100,000 emerged striga plants per acre) consistently increased the yield of grain. Three years of hand-pulling were necessary to reduce the effects of three years without hand-pulling. The residual effect of three years hand-pulling on yield

at Yandev was greater than the current effect of one year's hand pulling. (See also pages 10-11.)

In the Sudan, Andrews (1945 and 1948) stated that continuous hand picking before flowering helped to reduce seed in the ground but it was essential that the weed be pulled before flowering since green ovaries would produce viable seed on drying.

In Kenya, McDonald (1928) recommended hand weeding on lightly infected land but suggested the use of trap cropping with sorghum and maize when the land was heavily infested. Watt (1936) recommended planting sorghum in rows to make the weeding of striga easier. The removal of striga by handweeding was made compulsory at this period.

Dogget (1965) reported on the performance of sorghum varieties Bukura Mahemba (susceptible) and Dobbs (resistant) in experiments from 1950-57 in Tanzania. The mean number of emerged striga plants was 3,200 per acre on Dobbs, compared with 37,200 on Bukura Mahemba. The mean yields were 1,325 and 845 lb. grain per acre. The total striga plant numbers in heavily infested soils were estimated to range up

to two million, of which 10-30 per cent appeared above ground under undisturbed conditions. Grain losses brought about by striga were estimated at 2-3 lb. per acre per 1,000 striga plants. Dogget concluded that under East African conditions, S. hermontheca is at present best controlled by a combination of the use of resistant varieties and hand pulling.

ii. Mechanical destruction by catch cropping

Robinson and Dowler (1966) distinguished between true hosts, which had to be destroyed together with the parasite (catch crops), and immune or slightly susceptible hosts, which did not support the growth of the parasite well enough to set seed (trap crops). There is a fundamental difference between the two types of control. The catch crops depend on the mechanical destruction of the parasite while the use of trap crops is, in effect, a chemical method of control in which the chemical is generated in situ (see p. 30-32). Catch cropping for control of S. coccinea (=asiatica) was first advocated by Fuller (1900) when he recommended that witchweed and maize should be hoed out together. Macdonald (1928) was the first to advocate catch cropping to control S. hermontheca. He recommended

ploughing-in the catch crop just when the weed was coming in to flower. The catch cropping would have to be repeated several times over a period of years.

Wilson-Jones (1953c) advocated double catch cropping for farmers who could afford to lose one season's crop but considered that trap cropping was better for subsistence farmers. In the Gezira, Last (1960) observed that catch cropping with Sorghum sudanense for not less than five weeks significantly decreased the incidence of S. hermontheca in succeeding sorghum crops and sometimes increased grain yields.

In the Sudan, the residual effect of catch cropping with Sorghum sudanense was to reduce striga infestation from 31.5 per cent to 10.6 per cent in the sorghum crop growing in the year subsequent to treatment (Last, 1961). No references since 1961 to the use of trap cropping to control S. hermontheca have been seen.

iii. Stimulated germination by immune hosts (trap crops)

After Rose and Lochrie (1941) reported that non-gramineous hosts could germinate S. asiatica (see page 12)

a number of field experiments on S. hermontheca were started.

In the Sudan, Andrews and Wilson-Jones (1948) found that sorghum variety Feterita following Lubia dolichos fallow yielded more heavily than sorghum following bare fallow even though more striga emerged after lubia.

In Nigeria, Butler (1953) reported that trap cropping with cowpeas or sunflowers did not increase sorghum yields or reduce the amount of striga at Yandev. At Samaru, handpulling in continuous sorghum was compared with leguminous trap crops. In the test cropping year the lowest striga count was obtained on a treatment in which the striga had been hand pulled the previous year from a previous crop of sorghum. The rotational effect of the leguminous test crops, however, outweighed the reduction in the amount of striga and produced greater yields of sorghum grain following test crops, as compared with continuous sorghum in which the striga had been hand pulled.

In Tanzania, Dogget (1954a) found that one crop of cotton reduced the striga emergence at Lubaga to 1,160

parasites per acre compared with 4,010 per acre in continuous sorghum (variety Dobbs). In rotation experiments the results suggest that two years of cotton reduce the amount of striga in a subsequent sorghum crop.

No reference to the use of trap crops for control of S. hermonthecа have been seen since 1954 but Robinson and Dowler (1966) found that soybeans or field peas were about equal in effect with trap crops of millet, maize and sorghum for control of S. asiatica in North Carolina. All trap crops had to be grown for at least three years before a substantial yield increase was obtained, except that millet gave good yields after only two years of trap cropping.

iv. Stimulated germination by chemicals

Shaw, Sheppard, Robinson and Sand (1962) mention the possibility of stable soil active chemicals being used to stimulate striga seeds to germinate in the absence of a host. No reference to successful use of this method has yet been seen. (See pages 24-25)

The isolates from root exudates have so far been unstable and have lost their stimulatory power shortly

after exposure to air or moisture but Cook et al (1966) reported the isolation of a stable crystalline substance from the exudate of cotton roots which was a germination stimulant for S. asiatica.

v. Resistant host varieties

In the Sudan, Wilson-Jones (1953a and c) found that the sorghum variety Dwarf White Milo appears to have a very high degree of resistance to Striga hermontheca attack. Last (1960a) observed that more striga developed on the sorghum variety Debekri and Feterita. Last (1960b) reviewing the results of an experiment by Crowther started in 1941, found that sorghum variety Feterita was more heavily parasitised than sorghum variety Dwarf Hegari. Increasing the distance between plants to 100 cm reduced the total amount of striga per acre in Dwarf Hegari.

Williams (1959a) attributed the resistance of the South African sorghum variety Framida to the lower production of "germination stimulant" together with the production of a germination inhibitor. With other South Africa sorghums, resistance is due to mechanical or physiological obstruction.

Doughty (1941) found that varieties resistant to S. asiatica in Tanganyika were not necessarily resistant to S. hermontheca. Dogget (1952) reported that sorghum varieties Dobbs and P.41 showed signs of a high degree of resistance compared with other varieties. Dogget (1954a) showed that varieties P.41 and Dobbs had many fewer emerged striga parasites than varieties Bukura Mahemba and Ng'hollongo. Dobbs was the highest yielding variety. Dogget (1965) found that the resistant sorghum variety Dobbs was superior to the susceptible variety Bukura Mahemba both in yield and in the reduction of striga emergence. In a rotation trial, Dobbs had apparently reduced the reserve of striga seed. Dobbs germinated striga as freely as did Bukura Mahemba indicating that the resistance mechanism operates after the germination of the striga seed.

vi. Nutrients and organic matter

Pearson (1913) reported that 150 lb. and 300 lb. of sodium nitrate reduced the emergence of S. asiatica in maize in South Africa.

In Rhodesia, Timson (1938b) found that compost or Kraal manure (FYM) plus phosphatic fertiliser reduced

the emergence of S. lutea as compared with phosphatic fertiliser alone.

Porteres (1948) observed that the appearance of S. hermontheca was used as an index of soil fertility by the natives of West Africa. In his opinion 'it is not the growth of striga that results in deterioration of plantings but the poor condition of the latter (the soil) that leads to the spread of the parasite'. Porteres (1952) reported that in Niger, striga infected millet plants were given additional goat manure because experience had shown that striga was only dangerous on degraded soils.

In Nigeria, Butler (1953) obtained increased emergence of striga from the application of three tons of F.Y.M. in a low yielding trial at Samaru. He also observed a smaller yield response in sorghum to three tons of F.Y.M. where striga was present.

Wilson-Jones K (1953b) reported that chemical control of S. hermontheca resulted in good yields of grain on soil considered to be 'worn out' by continuous cultivation and soil erosion. Infestation by

S. hermontheca might be a major factor in the loss of productivity in the Sudan.

Basinski (1955) considered that striga was only one of the evils of intensive and prolonged mono-cropping. The introduction of an easy method of eradication might cause greater damage than the parasite itself.

Three papers by Last (1960a, 1960b, and 1961) provided further evidence in the Sudan. Last (1960a) observed that neither phosphorus nor potassium fertiliser affected the incidence of S. hermontheca or sorghum yields. On lightly infested sites where S. hermontheca was not damaging, 80 lb. of fertiliser nitrogen trebled grain yields but as the infestations increased in severity, the absolute gain decreased and the relative effects increased. Fertiliser nitrogen increased the yield of resistant variety Feterita, a striga resistant variety, more than the yield of the susceptible variety Debekri. The mean weights of S. hermontheca on Feterita decreased after adding 40 lb. of fertiliser nitrogen. Striga damage was never important until sorghum gave at least a 300 per cent

grain yield response to 80 lb. fertiliser nitrogen per acre. When the response to nitrogen was less than 300 per cent 2, 4-D herbicide did not increase yields. Last suggested that P and K might act similarly if they were deficient.

Last (1960b), reviewing the results of an experiment started by Crowther in 1941, found that fertiliser nitrogen (sulphate of ammonia) at 40 lb. and 80 lb. per acre progressively reduced the weight of striga and increased grain yields.

Last (1961) found that the incidence of S. hermontheca was not affected by 80 lb. of fertiliser nitrogen applied in the previous year but in another experiment there was a reduction from nitrogen and phosphate fertiliser applied in the previous year.

Agabawi and Younis (1965a) found that 40-120 lb. fertiliser N (as ammonium sulphate) did not affect S. hermontheca parasitising sorghum in pots. Striga attack reduced sorghum dry matter production by 53.3 per cent and nitrogen uptake by 54.3 per cent. Uninfested sorghum plants were more efficient users of fertiliser N.

Agabawi and Younis (1965b) found that fertiliser nitrogen delayed emergence and reduced the above ground growth of Striga hermontheca parasitising forage sorghum on heavy clay land in the Gezira.

No other references to the effect of nutrients on S. hermontheca but in North Carolina, Shaw et al (1962) reported that outstanding control of S. asiatica was obtained in 1959 by using high rates of fertiliser nitrogen per acre. Ammonium nitrate applied at 1,000, 2,000, and 3,000 lb. of N per acre prevented S. asiatica growth for the season. The 2,000 and 3,000 lb. rates were toxic to corn; 1,000 lb. was less injurious. In 1960, fertiliser N at 400 lb. per acre, three weeks before planting maize, gave full season control but reduced maize vigour. 200 lb. N and 2 lb. of fenac incorporated pre-planting, gave full season control of S. asiatica without damage to the crop.

vii. Soil acting herbicides

Herbicides which are applied to the soil and can be taken up from it by striga which has not yet emerged above ground, provide the only known method by which striga can be killed in this stage of development.

Nigeria

Butler (1957) reported small increases in yield from the use of 2,4-D at Yandev in 1955, 1956, and 1957. Goldsworthy (1960) reported no definite control of striga with MCPA or simazine.

Sudan

Wilson-Jones (1952) found that 1.2 to 1.6 # of 2,4-D applied two to four weeks after sowing gave the best striga control and increased the yield of sorghum. Application five weeks after sowing gave less efficient control. The variety Feterita was tolerant of 2,4-D but the variety Wad Fahl was killed by it. Wilson-Jones (1953a) found that lower dosages of 2,4-D (0.5 # to 2.0 #) gave good control of striga but also observed toxicity to the sorghum following spraying at two and three weeks after sowing but not at four and five weeks. The control from application at two and three weeks was significantly better than that at four and five weeks. Wilson-Jones (1956) appears to refer to the same work.

Last (1960a) found that 1.6 # 2,4-D was usually better than 0.8 # and that application three weeks after sowing was sometimes better than application at six weeks.

Yield increases caused by 2,4-D sprays were associated with the delayed emergence of striga. Where infection developed rapidly and the mean levels of infection were at least 20 per cent within 50 days of sowing, sprays increased both grain and straw yields; where infection developed slowly, only grain yields were increased. Although the 1.6 # rate of 2,4-D suppressed striga more than 0.8 #, yields of grain were affected equally. There was a positive interaction between fertiliser nitrogen and 2,4-D herbicide on grain yield.

Toms (1957) reported that 1.0 # of DMU (=diuron) or 2.0 # of simazine, applied pre-emergence, completely killed sorghum after germination. 0.5 # of diuron was tolerated by the sorghum and reduced the number of striga infested stands from 4 per cent to 0.5 per cent in the Sudan.

Tarr (1961) found that 0.8 # of 2,4-D applied two weeks after sowing reduced the incidence of striga on Pennisetum typhoides (bulrush millet) but increased yield only when the soil was deficient in nitrogen and when no fertilizer nitrogen was added. Nitrogen deficiency may limit yield more than striga on sandy

soils in the Sudanese rain grown cereal areas.

No reference to control of S. hermontheca by selective herbicides have been seen since 1961 but work on S. asiatica in maize has continued at North Carolina.

North Carolina, U.S.A.

Shaw et al (1962) reported that fenac, trifluralin, AMS, 2,4,5-T and erbon were promising materials for pre-emergent control of S. asiatica.

Dowler et al (1963) reported that 1-8 # fenac or 8-12 # TBA provided partial control of striga emergence but required two or three additional applications of 2,4-D at 1.0 # to prevent striga seed production. All rates of TBA and 8 # of fenac caused injury to maize, especially on soils containing much clay in the sub-soil.

Dowler et al (1964) reported on the value of 2,4-D, TBA and fenac for control of S. asiatica. Fenac at 4 # and 8 # gave the most effective witchweed control and resulted in the highest yields of maize. S. asiatica was not controlled by 2,4-D and TBA only gave

control at dosages which damaged the maize.

Egley and Kust (1964) reported that lanolin paste preparations of dicamba and TBA applied to the leaves (or by a split root technique to half the root systems) of maize and sorghum plants parasitised by witchweed caused abnormal development in the terminal and lateral buds of the parasite.

Other observations

Okonkwo (1966a) in laboratory tracer studies, showed that inorganic and organic substances travelled from the sorghum host to the Striga hermontheca parasite but that very little movement occurred in the reverse direction. The pattern of translocation suggested a possible use of selective weed killer applied as a foliar spray to the host plant.

Weise (1964) found that 0.5 # 2,4-D could reduce the yields of many sorghum hybrids (in Texas).

viii. Contact herbicides

Some herbicides kill striga species when they are applied to the aerial portions of the parasite.

South Africa

Watt (1909) reported that three per cent copper sulphate solution killed all S. asiatica after two or three days.

Saunders (1933) observed that maize was killed by 12.5 and 15.0 per cent solutions of sodium chlorate but a 5 per cent solution gave complete control of witchweed. The killing of maize was attributed by Saunders to translocation of the herbicide from the parasite but it seems more likely that it was taken up directly from the soil. Saunders also reported that striga regrowth had occurred in earlier experiments with copper sulphate.

Rhodesia

Timson (1931b) reported the use of 2 per cent sodium chlorate solution which gave complete control of witchweed with no regrowth from the underground parts. Calcium chlorate, potassium chlorate and copper sulphate gave the same results at a concentration of 5 per cent.

Timson (1933a) further reported on the use of sodium chlorate using 1.0 and 0.5 per cent solutions,

which killed the striga without regrowth. These observations have not been subsequently confirmed.

Martin (1949) reported complete control of witchweed in maize in Rhodesia by spraying 2,4-D repeatedly from the time of first emergence to the end of the crop. He suggested that two to three applications would be sufficient to prevent the parasite from flowering and seeding.

North Carolina

Shaw et al (1962) reported that S. asiatica parasitising maize was best controlled by repeated post-emergent applications of 2,4-D with or without fenac applied pre-emergent.

Robinson et al (1967) found that the best control of witchweed was obtained with monocropped maize, treated with 2,4-D at 0.5 # post emergent, as required. This treatment was better than rotations containing trap crops.

ix. Insect predators

Williams and Caswell (1959) reported that the larva of Smicronyx sp. (Coleoptera Curcilionidae) infected

the fruits (= capsules) of Striga sp. in Nigeria.

Milner (1966) also referred to the possible use of Smicronyx sp. as an insect for the biological control of Striga sp. in Tanganyika.

Davidson (1963) reported that, in Kenya, during 1960 and 1962, the commonest pest found was a small agromyzid fly, identified as a new species, Ophiomya strigalis Spencer. Attacks on S. hermontheca plants began when the plants flowered in late June and by early August, more than 90 per cent of plants had been attacked. No reduction in fruit or flower numbers were observed. Eurytoma sp., a gall forming species, also attacks S. hermontheca at Kibos, Kenya.

Sankaran and Rao (1966) listed the insects attacking Striga species (not hermontheca) in India.

The underground growth of striga in its seedling stages protects it from the attacks of most insects. The very ready formation of seed on very small plants and under unfavourable circumstances make this type of plant a difficult subject for biological control. Unless a suitable second host exists in the bush to

support the attacking insect, it can be predicted that biological control could reduce but not eradicate Striga species. Most of the insect pests so far reported do not prevent striga setting viable seed, even when the capsules are attacked. The development of a biological control which reduced the intensity of very severe striga attacks would be of great economic importance in subsistence areas, where the local varieties of sorghum are partly resistant.

(f) Methods used in investigating parasitism by Striga spp.

i. Laboratory techniques

The laboratory methods which can be used for investigating the parasitism of S. hermontheca are identical with those suitable for S. asiatica and in this section no distinction is therefore made between the species.

Pearson (1913) (seen only in abstract) performed a number of laboratory tests on S. asiatica germination but details of methods were not given. Saunders (1933) used water percolated through pots filled with sand in which maize plants were growing, to moisten layers of

blotting paper on which seeds of S. lutea had been sown. The blotting paper was placed in porcelain germination blocks and incubated at 25°C. This technique was used to measure the effect of different root exudates on germination; the effect of pH; the effect of temperature and the effect of variations in moisture. The technique used for measuring the effect of light was not described. To observe the growth of S. asiatica seedlings shortly after germination, Saunders used galvanised iron containers, each with a removable glass back and front. Clean blotting paper was inserted against the glass sides and the containers filled with fine sand. The sand was moistened and the containers laid on their sides to permit the removal of the glass plates. Striga seeds were then sown on the blotting paper and the glass replaced. Seeds of the host crop were then planted in the top of the container so that the roots of the resulting seedlings would develop between the blotting paper and the glass sides. The growth and development of the striga seedlings could then be easily followed. Other laboratory techniques described by Saunders were not relevant to herbicide investigations.

Doughty (1942) used glass tubes in place of

galvanised iron cylinders and used dampened rectangles of filter paper inserted in the glass tubes with the striga seed next to the glass. The tubes were filled with soil in which the seed of the host was planted. The tubes were then encased in removable tubes, having one surface matt black and facing inwards. Periodical inspection of the development of the host roots and the striga seed was thus possible.

Andrews (1945) used the bottom half of a petri dish of 11 cm diameter and 3 cm height, covered with blotting paper strewn with S. hermontheca seeds, so that the seeds lay against the glass. Seedlings of different potential hosts were arranged in holes pierced through the blotting paper, so that the root lay between the blotting paper and the glass, the hypocotyl and cotyledons standing vertical. The dish was nearly filled with clean sand and watered. The dishes, with their seedlings, were kept in a closed glass sided chamber, the floor of which was covered with sand kept permanently moist. Periodic observations through the glass bottom showed the course of the development of the root and the degree of germination of the striga seed.

Brown and Edwards (1945) incubated striga seeds at 22°C for 21 days on moist filter paper and then transferred them to another culture vessel moistened with a solution of the experimental substance. The seeds were then incubated for a further period at 22°C and finally at 34°C for 24-48 hours.

Vallance (1949), (1950), (1951a), and (1951b) used similar techniques to earlier workers but also used a Barcroft apparatus to measure the respiration of striga seeds.

Dowler et al (1964) measured the tolerance of germinating maize seedlings to herbicide solution in petri dishes. The petri dishes were incubated at 30°C for four days. Investigations on striga susceptibility to herbicides were not attempted in the laboratory and were confined to field experiments.

Okonkwo (1966b), (1966c) described the in vitro culture of Striga hermontheca to flowering and seed production in the absence of a host. 25 x 200 mm culture tubes filled with 20 ml of either Knops medium or 20 ml of Modified Murashige-Skoogs medium. The pH of the medium was adjusted to 5.5-5.8 and the medium

jelled with 1.2 per cent Difco agar. The tubes were stoppered with non-absorbent cotton wool wrapped with aluminium foil. The medium was autoclaved at 15 lb. pressure for 10 minutes and then slanted. Usually an aqueous exudate or extract of sorghum roots was incorporated in the initial culture medium to stimulate germination of striga seeds. Very full details of the preparation of the stimulant solutions were given. The striga seeds were pre-treated by incubating sterilised seeds on moist filter paper in sterilised petri dishes for 10-20 days in the dark at 25°C. They were then sown on the surface of the agar slant in each tube. All inoculations were carried out in a closed chamber which had been exposed constantly to ultraviolet radiations to assist in maintaining sterile conditions. The seedling growth was completed by transferring the two month old plants to 65 x 500 mm culture tubes. In most cases, the plants flowered after 4 to $4\frac{1}{2}$ months in culture. In the second paper (Okonkwo, 1966c) the effect of various sugars and glutamine on striga growth were observed. The technique seems to be ideal for observations on the direct effect of herbicides on striga at all stages of growth

uncomplicated by the presence of the host.

ii. Pot test techniques

It is sometimes difficult to distinguish between laboratory techniques involving the use of pots and pot tests proper. As used here, the term 'pot test' implies that the experimental plants are grown on to the end of the experimental treatment before any destructive sampling or microscopic examination of the roots occurs.

Doughty (1942) used 11 inch buckets as experimental units filled with a mixture of soil, compost, and 0.4 gm of Striga spp. seed (hermontheca or asiatica according to treatment). Twelve seeds of each host plant were sown per pot and subsequently thinned to leave 3 plants per bucket. The buckets were watered with nutrient solution twice a week. Periodical counts were made of the number of striga plants appearing in each bucket. The first trial was run from June to October and the later trials were of similar duration.

Andrews (1945) gave no details of his first pot technique except that five seeds were sown per pot into naturally infested soil. To ascertain the period

during which the sorghum seedlings became parasitised, 4 inch pots were filled with heat sterilised soil, into which was mixed 0,1 gm of striga seeds. The pots were each sown with a single sorghum seed, which had been soaked for 24 hours. Ten pots were washed out every week and the number of striga seedlings attached to the roots was counted. To investigate the effect of micro-nutrients on the resistance of the sorghum plant to striga, Andrews sowed six seeds coated with the micro-nutrient treatment into petrol tins (size not stated). Both Doughty (1942) and Andrews (1945) used the number of emerged striga plants per experimental unit as their main measurement of infection. The measurement of host production in pot experiments is not mentioned by either author.

Dowler et al (1964) measured the effect of fenac, 2,3,6-TBA and 2,4-D on the root weight of maize grown in pots. Experimental details were not given. No striga seed was sown in the pots. Parker (1965) referred to pot experiments on S. hermontheca but gave no details of technique.

Egley and Kust (1964) used lanolin paste preparation

of dicamba and TBA for experimental foliar application of herbicides to sorghum leaves. This technique could potentially be used for the screening of systemic herbicides in pots.

Agabawi and Younis (1965b) investigated different depths of sowing of S. hermontheca seed in pots but gave no details of experimental techniques. They observed the effect of striga attack on shoot and root weight of the sorghum host and observed that the effect was greatest at 0.5 cm depth. Agabawi and Younis (1965a) also measured sorghum production in pots when observing the effect of fertiliser on striga.

iii. Field experimental techniques

Northern Nigeria

One of the major practical problems in research on Striga hermontheca is whether the experiment should be sited on a naturally infested site (rare on experimental farms) or whether the site should be deliberately sown with striga seed.

Murty and Krishniah (1962) reported that the best method of infestation with Striga spp. (not hermontheca) was to sow the striga seed two inches below the host

cereal seed.

Gisborne (1953) classified individual plants according to their visible infestation status on a naturally infested site. He subsequently measured the individual yield of each plant. In later experiments, artificially infested sites were used, a non-experimental crop of sorghum being grown after infestation in the year before the experiment was started. Farmyard manure at one ton per acre was applied to the site in order to prevent the 'control' treatment plots failing to give any yield. The number of emerging striga, the yield of sorghum grain, the number of infested stands and the weight of hand pulled striga (where prescribed by treatment) was also recorded. These techniques were followed in general in the continuation experiments at Samaru, reported by Butler (1955) and (1956), but in 1955, transplanting of sorghum was tried as a means of avoiding the early loss of stand caused by striga attack. This failed completely in 1956 owing to drought (Watson 1957). The difficulty of building up striga infestations at Samaru was referred to. Goldsworthy (1960) reported a trial using MCPA and simazine at Yandev. The experimental details taken

direct from the logbooks were as follows:-

Yandev Factorial combinations of:-

(1) Nil

0.8 # MCPA. -

1.6 # Simazine

X

(2) 5 days before planting

2 weeks after planting

5 weeks after planting

X

(3) Nil

1 cwt. of sulphate of ammonia per acre

2 cwt. of sulphate of ammonia per acre

The nitrogen fertiliser was to be spread in three equal doses one week after planting, when tillers were forming (approximately 40 days later) and just before the appearance of the flag leaf (approximately 120 days after planting).

The herbicide was sprayed from a knapsack sprayer in 80 gallons per acre. During normal hand weeding, the striga was not to be removed.

The number of infested stands, weight of striga

one month before harvest, number of heads per sorghum stand, 200 head weight and score for total striga emergence were to be recorded.

In practice, a watering can was used instead of a knapsack sprayer. Farmyard manure was applied at three tons per acre over the whole trial. Soya beans were the preceding crop.

At Samaru, the experimental details were the same as at Yandev, except that the application of the herbicide was with knapsack sprayer at 16 gallons per acre. A basal dressing of 2 cwt. of superphosphate was given but no F.Y.M.

East Africa

Dogget (1954a) and (1954b) counted the number of striga plants emerging above ground and measured the yield of grain. Dogget (1965) also weighed the striga plants.

Sudan

Wilson-Jones (1953a) applied 2,4-D in 80 gallons of spray per acre post emergent to sorghum. The apparatus used was not stated. Last (1960) used a knapsack

sprayer to apply 80 gallons of diluted herbicide per acre.

Tarr (1957) showed that watering cans could successfully be used to apply auxin herbicides. The experiments in the Sudan recorded the yield of sorghum, the number of infested stands, the weight and number of emerged striga plants.

North Carolina, U.S.A.

The group working on control of S. asiatica in maize recorded the yield of grain and made subjective 'ratings' of witchweed control. The volume of diluted herbicide applied per acre was not stated. The emerged witchweed was controlled by periodical spraying with 2,4-D (method not stated), (Dowler et al, 1963 and 1964).

CHAPTER 3

THE PROBLEM

(a) Summary of the literature

The literature reviewed above clearly establishes a number of broad principles which govern the occurrence and severity of the attack of *Striga* spp. in sorghum.

Quantitative resistance to *S. hermontheca* attack has been observed in a number of varieties in East Africa, the Sudan and Nigeria. Several different mechanisms of resistance have been described, but no completely resistant varieties have been found. (Andrews, 1966), (Dogget, 1965), (Last, 1960b) and (Williams, 1959a).

High soil fertility, and in particular heavy applications of fertiliser nitrogen, reduce the amount of *Striga hermontheca* emerging and flowering above ground. The absolute response of sorghum grain yield to fertiliser nitrogen is reduced by striga attack but the relative response is increased (Agabawi and Younis, 1965b) and (Last, 1960a).

The only soil applied selective herbicides which

are reported to have been used against Striga hermontheca in sorghum are 2,4-D, first reported in 1952, MCPA, simazine, and diuron. Only in the case of 2,4-D has the correct dosage, selectivity ratio and maximum effect been fully worked out. In a series of papers, Wilson-Jones developed a technique of applying 1.2-1.6 # 2,4-D two to four weeks after sowing the sorghum. (Toms, 1957), (Wilson-Jones, 1952, 1953 and 1056) and (Goldsworthy, 1960).

Last showed that on the Sudanese varieties of sorghum, 1.6 # 2,4-D could reduce grain yields at low levels of striga infection. Last also found that 2,4-D herbicide only increased grain yields on highly nitrogen responsive sites. This implies that 2,4-D was not truly selective on Sudanese sorghums. At 1.6 # , 2,4-D always damaged the sorghum but this damage was masked at high levels of infestation by the greater benefit from the control of striga. Other disadvantages which complicate the use of 2,4-D are that it is not very persistent in the soil and it is very toxic to some other crops, notably cotton. (Last, 1960a)

Tarr reported that watering cans could be used to

apply 2,4-D to sorghum adjacent to cotton without serious losses in yield but this comparative safety is unlikely to be experienced except with experimentally controlled applications. (Tarr, 1957)

For the peasant farmer there is also the problem of storage of the herbicide. Contamination of seed of susceptible crops in store by vapour or dust transfer and possibly the use of old herbicide containers for storage would be difficult to avoid if the individual farmer had access to 2,4-D and its derivatives. There is therefore, the need for a herbicide which is more selective than 2,4-D and also better tolerated by cotton and other crops, which may be grown adjacent to, or are interplanted with, sorghum. The other specifications (which apply to all herbicides which are to be used by peasant farmers) are that it should be very cheap to use and that the mammalian toxicity should be low. In this last respect 2,4-D itself is undesirably toxic.

The work reviewed in Chapter 2 therefore shows that good quantitative control of Striga hermontheca can be obtained by use of three methods, which may be

summarised as follows:-

1. The use of resistant varieties of host cereals.
2. The maintenance of a high level of soil fertility, especially by application of fertiliser nitrogen.
3. The application of low dosages of 2,4-D post-emergent to sorghum and pre-emergent to striga.

In considering control methods it must also be remembered that S. hermontheca is primarily a problem for the African subsistence farmer in western, central and eastern Africa. At present, the unsophisticated hand farmer growing small areas of mixed crops, can only combat striga by use of resistant varieties and the practice of handpulling of all emerged striga plants. Handpulling is not a quick or cheap method of control. Several years have to pass before any clear improvement can be seen. Any relaxation in the discipline of pulling every striga plant out before it flowers can undo the effect of months of previous treatment. Only a proportion of African farmers can be expected to be able to practise the method perfectly, for long enough. Handpulling also has the defect that it fails to protect the crop before the striga emerges. 2,4-D and MCPA

do give pre-emergent control of striga with resulting increases in yield on heavily infested soils. They fail to control striga during the whole period of crop growth and, in addition, are toxic to some varieties of sorghum and many other crops.

A further difficulty hindering the adoption of these auxin herbicides is that the formulations have to be applied with a knapsack sprayer, though Tarr (1957) showed that a watering can could be used to apply the treatment instead. Whatever method of applying the liquid formulations is used, it involves the transport of heavy weights of water. Wilson-Jones (1953a) and Last (1960b) used 80 gallons per acre (weighing 800 lb). The use of low pressure medium volume (20-30 gallons per acre) floodjets specially developed for directed herbicide application still requires 200-300 lb. of water to be carried to the site. The use of low volume atomiser jets, developed for foliar applications of insecticide and fungicide, involves the risk of drift on to susceptible crops and also may not give adequate coverage.

Apart from one very restricted observation in the

Sudan (Toms, 1957) and two preliminary experiments at Samaru, there is no published record of other soil acting herbicides being tested against S. hermontheca. A suitable herbicide for peasant use would need to be more persistent than 2,4-D and much more selective. Most African hand farmers practise mixed cropping and an ideal herbicide should also be tolerated by at least some of the common mixed crops.

(b) The research objectives

1. The main object of the present investigation was to search for selective soil acting herbicides for pre-emergent control of striga in mixed crops. Subsidiary projects were

2. To search for selective contact herbicides for the control of emerged striga in mixed crops.

3. To develop simple methods of application suitable for use by unsophisticated farmers.

A fourth line of investigation which emerged during the course of the work is that some herbicides may promote the germination of striga. Brown and Edwards (1945) observed that both thiourea and allylthiourea

could replace 'germination stimulant', though neither material is stable enough in the soil to be of practical use. At least one herbicide now under development (methiuron) is a derivative of thiourea and is likely to be active and is said to have a short period of persistence in the soil. A full scale investigation of this aspect is outside the scope of this dissertation but herbicides which appear to stimulate germination are being noted for future investigation.

Three stages can be recognised in the development of a new herbicide practice. These are as follows:-

Stage I. The detection of desirable activity in a material.

Stage II. Evaluation in the environment in which it is to be used.

Stage III. Development of a practicable recommendation.

To detect desirable activity (Stage I) a pot technique was chosen for several reasons. Testing could continue throughout the whole year, only small amounts of herbicide were required, and it was expected that the variability would be smaller between pots than in

micro-plots in the field. The design of the pot tests was based on the proposition that a herbicide was displaying desirable activity when it increased the dry matter production of host plants, which were infested with striga. It was intended that treatments which gave statistically significant increases would be selected for field testing in Stage II. Experience showed that the interpretation of the results was complicated and a special ranking analysis was developed for the purpose (see pp. 77-81) to aid the assessment.

The main difficulty in carrying out Stage II has been the selection of suitable field sites. In 1967 only one site was sufficiently heavily infested for really accurate observations to be taken on control of striga but two suitable areas at Samaru were found for the 1968 season and heavier infestations were applied at the States experimental centres.

Stage III testing of formulations of materials discovered to have activity during this investigation has not yet been done.

S T A G E I

Screening for desirable activity

CHAPTERS 4 - 7

CHAPTER 4

POT TEST TECHNIQUE

(a) Experimental sorghum varieties

Short Kaura SK 5912: This is a reselection from SK 60 which is an improved Nigerian sorghum. It has a long growing season and can attain a height of 6 feet or more in the field. It has been crossed with exotic varieties to produce several of the new short stemmed, long growing season varieties and hybrids. For this reason it was chosen as the test variety for the first series of tests. It is partly tolerant of striga attack but can be reduced in yield or even killed by a heavy attack in the field. The variety has the undesirable characteristic (for pot work) of day length sensitivity. The variety took about 120 days to head during the dry season.

NK 300: This is an American hybrid sorghum; it is fairly short strawed and is day length neutral. It was used in two tests as a temporary replacement for SK 5912. It was somewhat more susceptible to striga attack than SK 5912. This variety took about 90 days to head under striga attack.

B 57: This is a variety of Indian origin, short strawed and day neutral. It was observed by Andrews (1967) to be very susceptible to striga attack. It has been very variable in growth under striga attack and it seems possible that the seed available at Samaru is not quite pure.

A 189: This variety is similar to B 57 but is less variable under striga attack. It has taken approximately 70 days to heading. So far, the supply of seed has been too small to use extensively in experiments.

(b) Experimental Units

Black polythene bags measuring 14 in. by 12 in., filled with 22 lb. of soil were used at first. When unobtainable, they were replaced by transparent polythene bags of the same size. Very high soil surface temperatures were experienced with the black polythene 'pots', which adversely affected sorghum germination. These were alleviated by hanging a gauze sheet 3 ft. above the soil surface. The transparent polythene 'pots' permitted striga plants to germinate and photosynthesise while still below the level of the herbicide

treated soil but were otherwise satisfactory. No nutrients were added to the pots.

(c) Sites of experiments

The first two experiments were conducted on a concrete plinth under a glass roof and with overhead irrigation. The remainder were in an insect-proof green house where the pots were sub-irrigated.

(d) Method of striga infestation

Striga seed heads were collected from sorghum fields at Samaru in 1966 and ground into a powder which was used as a source of striga seed. In the first two experiments, three grams of this powder was mixed with the soil in the pots before sowing the sorghum. In the later experiments, the powdered striga was placed in contact with the sorghum seed to increase the infestation.

Varieties B 57 and A 189 were so susceptible to striga attack that it was necessary to grow them for a week after emergence in clean soil before adding the striga seed to ensure their survival past the seedling stage.

(e) Application of Herbicide

The herbicide was applied as a soil drench

pre-emergent to sorghum in the earlier experiments and two weeks post-emergent to the sorghum in later experiments.

(f) Design of pot experiments

Partially balanced triple lattices with sixteen treatments were used. To reduce the residual variance between units in the later experiments, the units were ranked in order of sorghum vigour on the day the treatments were applied. This was intended to increase the variance between sub-blocks and replicates. The sub-blocks were not normally efficient, however, because random variability continued to develop after the treatments had been applied. In experiment AM 2 (67) R 68/18 for example, the efficiency in the analyses of all parameters was only 83 per cent. This experiment was therefore analysed as a randomised blocks design.

(g) Data collected from pot experiments

Five sorghum seeds were sown in each pot. One week after first sorghum emergence, the seedlings were thinned to one stand per pot. The thinnings were counted and weighed oven dry to record:-

i. Germination count and seedling weight.

The pots were inspected weekly to record:-

ii. Sorghum maturity state.

iii. Striga emergence date.

iv. Striga maturity state.

When at least one sorghum plant and one striga plant in the experiment had flowered, the experiment was terminated to record:-

v. Oven dry weight of sorghum at termination.

vi. Oven dry weight of striga at termination.

(h) The sequence of testing a herbicide

The first stage in testing a herbicide was to determine at what dosage it was tolerated by the host plant in the presence of striga. The second stage was to determine whether the tolerated dosage was selectively active against striga.

To avoid wasting experimental units, one dosage level of each herbicide was tested per experiment. If the sorghum did not tolerate the dosage, a lower dosage was tested in a later experiment. If the sorghum tolerated the dosage, a higher dosage was subsequently tested. Dosages were always increased or decreased by a factor of 3. The sequential

testing was continued until the highest dosage tolerated by sorghum could be determined.

If the herbicide showed selective activity against striga at any stage, the testing sequence ended and the material was nominated for field testing. Materials which were not selectively active against striga at the highest tolerated dosage were discarded.

A discussion of the limitations of this technique is given in Chapter 6, page 96.

CHAPTER 5

POT TEST ASSESSMENT

(a) Statistical analyses

i. Significance tests for multiple comparisons of means

According to Faulkner (1969), there is at present considerable uncertainty as to which test of significance should be used for multiple comparisons of means. It now seems clear that Duncan's Multiple Range Test is not accepted by many statistical authorities. Scheffe (1959) for example specifically rejects Duncan's test and points to errors in the original paper. Both Scheffe (1959) and Snedecor (1956) commend the method of Tukey (1953) which has the added advantage of being very simple to apply.

In the tables where significant differences occur, means which are not significantly different at P = 0.05 are given a common letter. If two treatment means do not share at least one common letter, they are significantly different. Where no letters are allocated to any treatment means, none of the differences are significant.

The standard error (E) below each array of means

is the conventional 'standard error of the difference of two means'. The least significant difference is therefore calculated from the following formula, LSD = E x D//$\overline{2}$ where D is the Tukey coefficient.

The same practice is used in the following chapters and appendices.

ii. Normalisation and missing data estimations

The distribution of the values of all arrays of data from pot tests were examined and transformed to normality where necessary by a computer program.

Multiple missing plot estimations (see page 83). were also done on the computer.

iii. Significance limit for correlations

The correlation calculated during the assessment procedure was the resultant of two demonstrably real and opposed relationships. No arbitrary significance limit was therefore imposed to restrict the adjustment of the dependent variable for variations in the independent variable.

Adjustment was always performed provided that the process reduced the residual mean error variance of the dependent variable.

(b) Assessment procedure

i. Host parasite relationships

The biological system consisting of a host and its parasite in the presence of a herbicide which can be differentially toxic to either is complex and difficult to analyse quantitatively.

Two contrasting relationships were observed to occur together in experiments after striga emergence had commenced:-

Case A: The relationship of newly emerged striga plants to host size and vigour.

Striga only emerged in pots containing sorghum which exceeded a certain limiting size. Newly emerged striga plants grew more rapidly on large vigorous sorghum hosts than on hosts at or near the limiting size. Therefore, in any experiment in which 'Case A' predominated there was a positive correlation between host and parasite weight.

Case B: The effect of size of mature striga plants on host size and vigour.

As the striga plants increased in size they progressively competed more severely with the host sorghum and reduced its rate of growth. The

proportionate size of a host plant supporting a mature striga plant was therefore reduced as the striga plant increased in size. Therefore, in any experiment in which 'Case B' predominated there was a negative correlation between host and parasite weights.

In an individual pot it was impossible to detect when 'Case B' became dominant over 'Case A' as the parasitism developed, though the extreme states of either 'case' were readily distinguished by eye.

When an experiment was terminated, it invariably contained pots with all stages of parasitism. The sign of the correlation between all the sorghum and striga dry weights in the experiment was therefore used to determine which relationship predominated at the end of the experiment.

When the correlation was positive, the striga dry matter yields were treated statistically as a dependent variable but if it was negative, the sorghum dry matter yields were considered to be dependent.

The complications introduced by the presence of emerged striga made the parameter 'Host dry matter yield' inadequate to describe herbicide performance completely and a modified parameter based on a ranking

procedure was used instead.

ii. The assessment of herbicidal activity using a ranking procedure

The ultimate criterion of herbicidal selectivity is the biological success of the host in comparison with that of the parasite. The factors used in assessing herbicidal activity in these pot tests were:-

a. The maturity achieved by the parasite at the terminal date,

b. The maturity achieved by the host at the terminal date.

c. The dry matter yield of the host.

d. The dry matter yield of the parasite.

These four factors were used to rank the pots of an experiment in descending order of herbicidal effectiveness. They were first grouped qualitatively into categories defined by the maturity states of host and parasite and were then ranked quantitatively within each category.

Grouping into categories

The categories were based upon the following states of host and parasite at the termination date of the experiment.

Table 2: Categories used in pot test assessment

Description of state	Maturity score Host(H)	Parasite(P)
Completely absent	1	0
Absent but foliar symptoms on host	n.a.*	1
Dead	1	2
Vegetative but too small to support striga	2	n.a.
Vegetative, large enough to support striga	3	n.a.
Vegetative striga	n.a.	3
Sorghum heading	4	n.a.
Pink flowers visible	n.a.	4
Sorghum at or past anthesis	5	n.a.

* n.a. = not applicable

The category numbers were then calculated according to the formula C = 5H-P where H and P were the maturity scores.

The pots in which the relative biological success of the host was greatest were grouped into the highest numbered categories by this procedure.

The Ranking Procedure

Within each category the pots were ranked in descending order of herbicidal effectiveness using a quantitative ranking parameter. The parameter used

varied according to the category into which the pot was grouped. The three parameters used are defined in Table 3.

In categories in which emerged striga occurred the 'dependent variable' (see p. 76) was used as the ranking parameter and adjusted so that the value of the 'independent variable' also had its effect in determining the herbicidal rank of the pots. For all categories the adjustments were as defined in Table 3.

Table 3: Definition of ranking parameters within categories

1. Emerged striga absent from pots

Ranking parameter:- Unadjusted sorghum dry matter yield.

2. Emerged striga present in pots, 'Case A' dominant in experiment

Ranking parameter:- Adjusted striga dry matter yield.

Adjustment added to the parameter value $= b(\bar{H}-H)$ where:-

b = the regression coefficient of striga dry matter yield on sorghum dry matter yield.

$\bar{H}$ = the average sorghum dry matter yield.

H = the sorghum dry matter yield in the pot whose value was being adjusted.

3. Emerged striga present in pots, 'Case B' dominant in experiment

Ranking parameter:- Adjusted sorghum dry matter yield.

Adjustment added to the parameter value $= -b(\bar{P}-P)$ where:-

b = the regression coefficient of sorghum dry matter yield on striga dry matter yield.

$\bar{P}$ = the average striga dry matter yield.

P = the striga dry matter yield of the pot whose value was being adjusted

After ranking within categories, an overall rank within the complete experiment was given to each pot, starting with the highest numbered category and ending with the lowest.

The ranks were then converted into 'rankits' (Bliss, 1967) as recommended by Fisher and Yates (1963) The rankits were then analysed statistically. This ranking procedure is discussed on pages 108-113.

This parameter was an estimate of the complete effect of the herbicide as measured by all the recorded factors.

iii. Host dry matter yield

The 'rankit' values calculated in the preceding section did not indicate whether the herbicide mainly affected the striga or the sorghum. An increased rankit value could be caused either by a decrease in the striga vigour and maturity or by an increase in sorghum vigour and maturity.

The host dry matter yield was used to measure the direct influence of the herbicides on the host. When 'Case A' predominated in the experiment, the sorghum dry matter yield was treated as an independent variable, and was statistically analysed without adjustment.

When 'Case B' predominated, the sorghum dry matter yield in pots containing emerged striga was treated as a partially dependent variable and adjusted to compensate for variations in the striga dry matter yield.

The adjustment used in each pot was:-

$$B = b(\bar{P}-P)$$

Where:-

b = the regression coefficient of sorghum dry matter yield on striga dry matter yield.

$\bar{P}$ = the mean striga dry matter yield in the experiment.

P = the striga dry matter yield in the pot.

The adjusted values were combined with the remaining (unadjusted) values in the experiment and analysed statistically.

This procedure is discussed on pages 114-115.

The parameter was used to observe direct herbicide toxicity effects on the sorghum plants.

iv. Parasite dry matter yield

When 'Case A' predominated, the striga dry matter yield was treated as a partially dependent variable and adjusted for variations in sorghum dry

matter yield.

The adjustment used in each pot was:-

$$A = b(\bar{H}-H)$$

where:-

b = the regression coefficient of striga dry matter yield on sorghum dry matter yield.

$\bar{H}$ = the mean sorghum dry matter yield in pots containing emerged striga.

H = the sorghum dry matter yield in the pot.

When 'Case B' predominated, the striga dry matter yield was not adjusted.

Pots with sorghum host plants which were dead or too small to support emerged striga were treated as 'missing' in the statistical analysis.

This parameter was an estimate of the direct control effects of the herbicides on striga growth above ground.

(c) The detailed assessment of pot test AM2(67)R68/18

i. Summary of experimental procedure (See Appendix 3 for full description)

This experiment was selected for description as an example of the assessment technique developed to date.

Site	Botany greenhouse
Experimental soil	ex - 5 ton/ac FYM continuous cotton plots on monocropping and rotation experiment, on the agronomists farm, Samaru
Experimental units	Transparent polythene bags
Experimental variety	A 189
Design	3 replicates of 16 treatments, in a partially balanced triple lattice
Sowing date	18.10.1968
Germination date	21.10.1968
Striga 'seed' applied	28.10.1968
Herbicide treatments applied	4.11.1968
First emergence of *striga*	27.11.1968
Termination date	27.1.1969

The striga trash was applied to the surface soil one week after sorghum emergence and the herbicidal treatments were applied one week later.

Before treatment, the units were ranked in experimental order in descending order of sorghum vigour.

This was intended to take advantage of the lattice design by reducing intra block error.

The newly emerged sorghum seedlings were treated with Bidrin insecticide to control a mite attack on 11.11.1968.

The experiment was terminated when at least one sorghum plant had flowered and set seed and at least one striga plant had developed pink flowers.

ii. Host-parasite relationship

The 28 units in which striga had emerged were examined to determine whether the sorghum weights and the striga weights were positively or negatively correlated.

The correlation was positive, which implied that the striga weight was dependent on the sorghum ('Case A'). The best correlation was between the logarithm of the striga weight (+ .9999) and the untransformed sorghum weight.

Regression coefficient 0.208. Variance ratio 3.27

RSQ = 0.112

The regression accounted for only 11 per cent of the log striga weight variance but was significant at P = 0.1. This relationship was therefore used

to adjust the log striga weights.

iii. Ranking procedure

At the termination date, the smallest sorghum plant to support striga emergence weighed 0.39 g. Any plants smaller than this were arbitrarily defined as 'too small to support emerged striga' and were given a maturity score (H) of 2 (see Table 2, page 78).

The 48 units in the experiment were distributed into categories as shown in Table 4.

Table 4: Distribution into categories

Maturity scores H	P	Category	Number in category	Range of ranks
5	1	24	3	1-3
5	3	22	16	4-19
4	1	19	1	20
4	3	17	2	21-22
3	1	14	2	23-24
3	3	12	9	25-33
3	4	11	1	34
2	1	9	4	35-38
5	0	5	10	39-48

The procedure for giving overall ranks to individual units is shown in Table 5 for one

replicate of the experiment. The parameter used for ranking within category is underlined in the table.

The experiment mean sorghum weight (in pots with emerged striga) was 2.17 g. The adjustment applied to the log striga weights was therefore A = 0.208 (2.17 - H) where H was the weight of sorghum in the pot.

The final stage in the process was the statistical analysis of the array of 48 rankit values. (See appendix 5(1).)

Table 5: Ranking of units for analysis

Column	1	2	3	4	5	6
Unit number	Category	Sorghum weight g.	Adj. log striga weight	Rank in category	Rank in experiment	Rankit value
1	12	0.61	-3.67	1	25	-0.03
2	12	0.99	-1.34	5	29	-0.24
3	12	0.68	-0.89	7	31	-0.34
4	22	1.29	-1.72	7	10	0.84
5	22	2.58	-0.91	12	15	0.52
6	22	1.60	-0.34	15	18	0.34
7	5	0.0274	-	5	43	-1.19
8	11	1.12	-0.12	1	34	-0.52
9	22	2.29	-1.36	9	12	0.70
10	22	3.65	-1.98	3	6	1.19
11	12	2.03	-1.96	2	26	-0.08
12	5	0.0240	-	6	44	-1.31
13	9	0.28	-	1	35	-0.58
14	22	1.59	+0.07	16	19	0.29
15	12	0.39	-1.35	4	28	-0.18
16	9	0.0304	-	4	38	-0.77

iv. Sorghum dry matter yield

The untransformed data was analysed. There were no missing plots but the weights of 10 dead plants which had died before termination were included (see Appendix 5(2)).

v. Striga dry matter yield

The striga dry matter yield values were adjusted to compensate for variations in the sorghum dry matter yield. In this experiment, the adjustment applied to each value was $A = b(\bar{H}-H)$ and was exactly equal to the adjustment applied to the same variable when it was used as the ranking parameter (see page 80).

The adjusted values were therefore those given in column 3 of Table 5.

There were 14 units in which the sorghum was dead or too small to support striga emergence. The adjusted log striga weights were normally distributed and were used for statistical analysis. The 6 units containing large sorghum plants but no emerged striga were given the log value of 0. When analysed, the data array therefore contained 14 missing plots and 6 plots with zero values (see Appendix 5(3)).

vi. Results of experiment AM2(67)R68/18

The results derived by the procedures described in preceding sections are shown in Table 6. All treatment differences are expressed as 'responses', i.e. deviations from the mean of the control treatment. Least significant differences were calculated by use of the Tukey test. No statistically significant treatment differences occurred. No standard error can be quoted for the retransformed striga dry matter responses.

vii. Conclusions derived from Test 18

A desirable herbicide should reduce striga growth and increase sorghum without seriously retarding the maturity of the sorghum.

The following notes discuss the materials included in the test.

Nitralin and pyrazon

The two top ranked treatments were undoubtedly active against striga. In the nitralin treatment, three sorghum plants set seed and only two out of three produced emerged striga just before the end of the experiment. The growth in the pyrazon treatment was even more vigorous but received a lower ranking

because the sorghum plants were slightly less mature and one of them had not completed heading by the end of the experiment. Striga control also broke down earlier, resulting in a heavier weight of striga. Both these materials merited inclusion in field trials.

Noruron/DSMA and chlormequat

It is difficult to explain the results obtained with the noruron-DSMA formulation. This is basically a post-emergence contact treatment. Noruron itself has little detectable action against striga and the selective activity was attributed to the DSMA. The treatment was remarkable for the large number of striga plants which emerged per pot. An average of 17 emergences which were mostly shortlived occurred in the pots of this treatment. In other treatments, a maximum of two emergences normally occurred.

A further field test pre-emergent to striga will have to be done when more clearly promising materials have passed through this stage.

The chlormequat treatment produced two rather small plants which set grain and one plant too small to support striga which died. Only one unit produced

Table 6: Selectivity of herbicides against S. hermontheca

Results of pot test AM2(67)R68/18

Deviations from untreated means

Herbicide name/dosage #		Percentage responses Sorghum dry matter	Striga dry matter	Rankit response	Indicated future testing
Nitralin	1/3	366	-39	1.73	Field test
Pyrazon	1/3	669	118	1.48	Field test
Noruron/DSMA	1/3	390	-32	1.27	Field test
Chlormequat	1/3	137	438	1.10	Defer
R7465	1/3	211	-55	0.98	Defer
IT3233	1/9	5	-98	0.66	Defer
Chloramben	1/9	284	-46	0.51	Field test
Maleic hydrazide	1/3	76	183	0.48	Retest at 1
Monolinuron	1/3	140	-74	0.45	Field test
Fluometeron	1/27	191	132	0.31	Discard
Noruron	1/3	-20	-86	0.30	Retest at $\frac{1}{9}$
'Azak'	1/3	146	-4	0.11	Retest at 1
CP50144	1/3	-18	1811	0	Discard
'Nortron'	1/3	-76	912	-0.19	See discussion
Triallate	1/3	41	54	-0.42	Discard
S.E. of response		±219	n.a.	±0.763	

striga but this was relatively large and vigorous so that, on adjustment, a large striga treatment mean was recorded. The two surviving plants were among the earliest to head and were described as 'precociously' mature' in the notes on this treatment. It seems likely that the increased sorghum dry matter production was due to earlier host maturity caused by growth regulator activity rather than by any genuine selective activity against striga.

R7465, IT3233, chloramben and monolinuron

All these materials showed moderate selectivity at the dosages tested. The two coded materials were not available in quantity and further work was deferred until their commercial future was settled. Neither chloramben nor monolinuron would have been scheduled for early field testing from the results of this trial but, in fact, a granular formulation of chloramben was available for field testing in 1968 (see Chapter 8).

Fluometeron, CP50144 and triallate

These materials failed to reduce striga growth at the highest dosages tolerated by sorghum. They were therefore discarded from further testing as insufficiently active.

Noruron

This material is recommended for pre-emergent

weed control in sorghum. In this test, both sorghum dry matter production and striga dry matter production were slightly depressed. Noruron was therefore listed for subsequent retesting at a lower dosage.

'Nortron'

This material was accepted for testing with only a verbal assurance about its mammalian toxicity. It was later reported to be very poisonous. No further testing was undertaken and the herbicide sample was destroyed.

Azak and maleic hydrazide

Neither of these herbicides was selective at the dosage used in the trial.

The results of this experiment illustrate the problems of interpretation. The main problem is that the presence of striga in the experiment results in very variable growth by the sorghum host. This variability occurs whether or not herbicides have been applied. The weight of the sorghum plants in the three control units in the experiment were 0.68, 0.19 and 0.06 grams respectively at harvest. The first grew vegetatively and supported emerged striga. The second survived to the end of the experiment but

never grew large enough to support emerged striga. The third died after ten weeks growth. All these plants were heavily parasitised by striga and showed acute foliar symptoms.

CHAPTER 6

RESULTS OF POT TESTS

(a) Tabulated results of pot tests

i. Explanatory notes

The tables in Appendix 4 present the results for herbicides whose sequential testing has been carried through to a decision to discard or to test further in the field. A number of other materials are still under test at an earlier stage in the sequence.

The initial stages of testing to ascertain a tolerated dosage at which the sorghum might be expected to grow to maturity are omitted from the tables.

Where more than one test was necessary to determine selectivity, the test results are set side by side, with the earliest results on the left. Those test results in which the variety SK 60 was used and striga dry matter figures are not given are less reliable than those in which the shorter term, day length neutral varieties were used.

The combination of the three parameters quoted in the results is considered to give the best indication of selectivity. The 'Effect' quoted is always

the deviation of the herbicide treatment mean value from the untreated control mean. The dry matter production 'effects' are made as comparable as possible between successive experiments by expressing them as percentages of their respective untreated control means.

As pointed out in Chapter 5, it is unwise to make multiple comparison significance tests at present, owing to the disagreement between statistical authorities as to which tests should be used. No standard errors are therefore quoted in these tables.

The herbicides have been grouped according to the system used in the British "Weed control handbook" 5th edition and the common names and chemical names are also copied from this book. The chemical names are not necessarily those most often quoted but are more systematic and consistent than those given in the "Herbicide handbook of the Weed Society of America", which is the other recognised authority.

ii. Summary of results

Though it was difficult to obtain statistically significant differences between the herbicide treatments, the positive indications obtained from the pot

tests have invariably been confirmed whenever it has been possible to test them in the field.

At the start of the investigations in 1967, only the phenoxyacetic acids were certainly known to be active against Striga hermontheca, though it seemed likely that the benzoic and phenyl acetic acid groups which were reported to be active against S. lutea would also be active against S. hermontheca.

The pot tests have indicated that selectivity also exists amongst several other herbicide groups. It is difficult to distinguish any relationship between selectivity and chemical composition. Indeed, selectivity frequently appears to occur in only one of a group of closely related herbicides. For example, ametryne (2-ethylamino-4-isopropylamino-6-methylthio-1,3,5,-triazine) is very active and selective, whereas prometryne (2,4-bisisopropylamino-6-methylthio-1,3,5-triazine) is toxic to sorghum and apparently completely inactive against striga.

Table 7 shows the wide range of herbicide groups which appear to possess at least one selective herbicide.

Absence of demonstrable selectivity in pot tests

did not definitely preclude the possibility of useful selectivity being observed in the field but no herbicide treatment which failed to control striga in pots was subsequently observed to do so in the field. It was observed, however, that sorghum in the field was much more resistant to directed soil applications of herbicides than when it was grown in greenhouse pots. This has the 'fail safe' advantage that the pot tests tended to under-estimate the selectivity ratio in the field, especially when the herbicides were applied at the time of striga emergence.

The importance of using the correct method of application is demonstrated by the behaviour of triallate. When applied as a soil drench in pots, the herbicide was not selective, but when incorporated in the field it was strongly active and apparently selective at a very low dosage (see p. 144).

Table 7: Herbicides indicated by pot tests to possess selective activity against Striga hermontheca parasitising sorghum

Group	Herbicide name	Type of activity confirmed by field tests
Carbamates	Chlorbufam	
Thiocarbamates	Sulphallate	Soil
Ureas	Linuron	Contact
Diazines	Bromacil	Soil
	Pyrazon	Soil
Triazines	Atrazine	Soil, foliage translocated
	Ametryne	Soil, foliage translocated
	GS 14260	Contact
Esters	Flurenol	
Nitriles	Chlorthiamid	Soil
Phenoxy propionic acids	Mecoprop	Contact
Benzoic and Phenyl-acetic acids	Chloramben	Soil
Anilines	Nitralin	Soil
Ethers	C 9122	Contact

(b) Discussion

i. The practical aspects of the experimental method

At the time that pot tests were started in 1967, they were intended to provide an economical way of screening a large number of herbicides. As can be seen in Appendix 4, a large number of herbicides were screened but it proved unexpectedly difficult to obtain clear-cut results. This may have been due to the absence of any outstandingly selective herbicides but might also have been due to defects in the experimental method.

During the course of the pot tests, the following limitations of the technique became evident.

1. The experimental designs did not include a striga free control treatment. Several attempts were made to grow pots which were free from striga but it never proved possible to do so in an experimental design which also contained striga infested pots. Invariably, one or more of the 'striga free' pots produced vigorous striga plants. It was therefore reluctantly concluded that, with the staff and accommodation available, it was difficult to avoid chance contamination by infested soil or wind blown

seed. In future tests it will be possible to use a herbicide of known activity as a 'high standard'. In all the completed trials reported here, any improvement over the striga infested control was assumed to demonstrate selectivity against striga.

2. Only one sorghum plant was grown per pot. It was suggested that by growing more than one plant, a more reliable estimate of dry matter production would be obtained. When three were grown per pot in technique development experiments, it was found that one plant normally grew much larger than the others while there was still a proportion of pots in which all plants died before the termination date. The standard error was 70% of the general mean, which was of the same order as the error when the plants were grown one to a pot. Categorisation was very difficult because it was impossible to know which striga plants were parasitising which sorghum plants and it was difficult to decide whether the differences between the hosts were due to mutual competition or differential parasitisation.

3. Sorghum growth would have been more even if basal fertiliser were added to all the pots. This

was not done in the series of tests reported here because it was thought that higher fertility would reduce striga attack. In the light of knowledge obtained from field tests, it now seems that fertiliser could be added without affecting striga attack and this will be done in future tests.

4. The main object of the present investigation was to discover selective soil acting herbicides for pre-emergent application to the sorghum. Though this remains the ultimate object, experience in the field indicates that the first practical application of soil acting herbicides will be post-emergent to sorghum. In future tests, therefore, herbicide application will commence post-emergent. This will have the advantage that chance differences between units will be better established so that the pre-treatment ranking can be done more certainly. (See pages 84-85).

5. The variability could be further reduced by sowing more pots than are required for the experimental design so that unusually vigorous or feeble plants could be eliminated before treatment.

ii. Methods of measuring herbicidal selectivity which were tried and rejected

Several control parameters were used and discarded while the present method of assessment was being developed. The discarded parameters are described below.

Delay in striga emergence

This is closely related to host vigour and maturity and experience in the early tests showed that it was a very poor measure of herbicidal efficiency. Delay in striga emergence could be caused by any one of the following causes:-

1. Poor sorghum growth caused by intense underground striga attack.
2. Poor sorghum growth caused by herbicide toxicity.
3. Absence of effective striga parasitism. (This does not occur with the technique described in Chapter 5)
4. Genuine selective herbicidal control of striga.

The paradoxical result was that a moderately selective treatment, giving early striga control which stimulated sorghum growth often supported striga emergence earlier than either the untreated control or a herbicide toxic to the sorghum in the

same experiment. It was also observed that the time of emergence varied greatly from experiment to experiment and made comparison of results difficult between experiments.

Sorghum grain yield

This parameter is a good measure of the effect of partial striga control in increasing sorghum vigour and maturity but gives no direct measure of the effect of the herbicide on the striga. It has also the severe practical disadvantage that pot experiments taken to yield are unnecessarily long in duration and expensive. A further disadvantage which was experienced in practice was that variability between pots in a treatment tended to increase as the experiment continued and the effect of the striga parasitism became greater.

Striga dry matter yield

The unadjusted striga dry matter yield was a poor measure of herbicidal selectivity for the reasons given when discussing 'Delay in striga emergence'. It has the additional disadvantages that many pots produced no striga; the distribution of the values from those that did was not normal and it was difficult

to know what values to use in pots where the sorghum died or remained too small for striga emergence to occur.

Subjective scores or ranks for herbicidal selectivity

Attempts to give 'scores for herbicidal performance' to individual pots or to rank treatments by eye were defeated by the variability which occurred between pots in the same treatment. One method which seemed slightly easier to apply was to take the median plant of each treatment and use this for ranking, but this method could be misleading in that it only used one third of the pots for treatment comparisons.

None of the methods of measurement discussed above were able to use and express all of the information about herbicidal action which was available from the tests. For this reason, the objective ranking procedure described in Chapter 5 was developed.

iii. Categorisation for the ranking method

The grouping of pots into categories was a two stage process primarily using the maturity score of the host and secondarily subtracting the maturity score of the parasite.

The logical basis for this procedure was the proposition that the primary purpose of a herbicide

treatment was to increase grain yields in the field and secondarily to reduce or prevent striga seed production.

iv. Choice of termination dates for experiments

The duration selected for each experiment was the period it took for at least one sorghum plant and one striga plant to flower. If one specimen of each species was able to flower, then it followed logically that the others could have done so as well, unless constrained by herbicidal effects or the host-parasite relationship.

This stage in the experiment was therefore a convenient point at which to observe maturity differences in both host and parasite. It was further found in practice that at this stage, most experiments were close to the point where 'Case B' became dominant over 'Case A' in the pots with emerged striga. As a result, the net correlation between sorghum dry matter yield and striga dry matter yield was usually slight and the corrections derived from it were small. This was desirable in that real rather than estimated values could be used for ranking (and for estimations of dry matter yield parameters).

v. The selection of a ranking parameter

When emerged striga was absent from a category, the best quantitative ranking parameter for plants in the same stage of maturity, was host dry matter yield.

When emerged striga was also present, it was necessary that the parameter should express the status of both host and parasite.

In Chapter 5 (page 75) it was explained how a positive correlation between host and parasite could be expected while the striga was newly emerged, which would change to a negative correlation as the parasitism progressively retarded the growth of the sorghum.

These two conditions which I have termed 'Case A' and 'Case B' respectively, were always present together in experiments at termination but it was only possible to ascertain which predominated over the other by observing the sign of the correlation between host and parasite. It could then be stated that if the correlation was positive, the majority of the pots were in the 'Case A' condition and that striga vigour was partially dependent on host vigour in them. Alternatively, a negative correlation indicated that sorghum growth was being retarded by striga parasitism in a

majority of pots. (Sorghum vigour dependent on striga vigour.)

Only the dependent variable in each case could legitimately be adjusted in value to express variations in the independent variable. The appropriate dependent variable was therefore selected as the ranking parameter in categories containing emerged striga.

vi. Adjustments to the ranking parameters

Case A (Correlation positive)

The striga dry matter yield values were ranked in inverse order of size to express herbicidal efficiency. Hence a negative adjustment resulted in an increase in an increase in rank.

An above average sorghum dry matter yield should cause an increase in rank. In the adjustment formula $A = b(\bar{H}-H)$, b = regression coefficient of striga on sorghum, is positive, H (the sorghum dry matter yield) is greater than $\bar{H}$, hence $(\bar{H}-H)$ is negative. 'A' is therefore negative and causes an increase in rank.

This adjustment is identical to the normal adjustment of a dependent variable to compensate for variations in the independent variable.

Case B (Correlation negative)

The sorghum dry matter yield values were ranked in descending order of size to express herbicidal efficiency. Hence, a negative adjustment resulted in a reduction in rank.

An above average striga dry matter yield should cause a reduction in rank. The adjustment formula used to compensate for variations in the independent variable (striga dry matter yield) would be $B = b(\bar{P}-P)$. As both b and $(\bar{P}-P)$ are negative, their product is positive and the use of this expression would therefore result in an above average striga plant giving an increase in herbicidal rank.

The logical basis for using the expression $B = -b(\bar{P}-P)$ was that the sorghum dry matter yield increase had already been retarded by striga. The reduction in potential yield was equal to $b(\bar{P}-P)$. In addition, the pot had also produced the striga dry matter yield P, which had caused the reduction. This was expressed by reducing the ranking parameter (sorghum dry matter yield) by an amount calculated to be equal to the reduction which it had caused.

The effect of this adjustment is to express the

Table 8: The effect of atypical plants on treatment means of assessment parameters

Case	Correlation	Dependent variable	Atypical condition		Effects of adjustment	
			Striga	Sorghum	Dependent variable	Rankit
A	Positive	Striga D.M.	Large, mature	Small, immature	Increase striga	Reduce
B	Negative	Sorghum D.M.	Small, immature	Large, mature	Increase sorghum	Increase

The adjustment of the dependent variable value in an atypical unit always increased the estimated value. An atypical unit with poor striga control (Case A) underestimated the true selectivity by reducing the rank while in Case B with good striga control the selectivity was overestimated by increasing the rank.

The bias introduced in this way could be substantial in the dry matter production parameters but was always small in the rankits because the order of rank was decided by category and the ranking parameter within categories was always an expression of both host and parasite vigour. For this reason, the rankit treatment mean was always considered to be the most reliable and important measurement of herbicide selectivity.

viii. Statistical distribution of data

The examination of the statistical distribution of the data showed that, in most experiments, the sorghum weights were normally distributed and that the striga weights were lognormally distributed.

and some treatment means were based only on one or two measured values, which reduced the accuracy of the treatment comparisons.

(c) Conclusions

1. The pot tests were a satisfactory primary screen for detecting selective herbicidal activity against Striga hermontheca parasitising sorghum but were rarely accurate enough to give statistically different treatment means. This was mainly due to ambiguity in interpreting the results when emerged striga was present at the termination of the experiment.

2. The use of a parameter based on objective ranks solved some of the problems of analysis and is considered to give a good measure of overall herbicidal activity. In contrast, the adjusted dry matter yield parameters could be inaccurate for the reasons given in the foregoing discussion and were primarily of use in diagnosing how the herbicide acted.

3. If emerged striga had been absent, the size and maturity of the sorghum plants would have expressed only the direct effects of the herbicide treatments. Future development of the experimental method will, therefore, attempt to measure the dosage of herbicide

required to give complete control of striga emergence. The toxicity to sorghum and the overall selectivity of the dosage applied, would continue to be measured by the adjusted sorghum dry matter production and the rankit parameters already described.

CHAPTER 7

FIELD SCREENING TESTS

(a) Equipment and experimental method

i. Equipment used

Log dilution sprayer

An M.D.M. 'Minilog' sprayer was modified by substituting the standard two and three jet boom supplied with the sprayer for a single wide angle jet. As supplied with '00' ceramic jets, the standard booms required rather high pressure (40-60 lb/sq.in) to obtain an evenly distributed spray fan and produced a lot of fine drifting mist. This was quite unacceptable where herbicides were being applied in the vicinity of breeders' crops in experimental stations. The substitution of size '0' or '1' ceramic jets gave an unacceptably high gallonage per acre and resulted in an effective plot size of 2 x 4 yds.

Eventually a single wide angle plastic 'floodjet', operating at a pressure of 20 lb/sq.in, was found to give good coverage over a width of 6 ft. and to permit a plot length of 10 yd. No drift at all occurred with this arrangement and the poorer distribution within the fan was accepted because any variations in

dosage caused in this way would be negligible compared with the reduction in dosage caused by the dilution procedure. The dosage was reduced by a factor of approximately 0.73 per yard length of plot, with the container volumes normally used in the apparatus.

Constant dosage sprayer

A standard design Cooper-Pegler 'Policlair' sprayer was used for all constant dosage and spot spraying herbicide applications. By replacing the uptake tube into the pressure cylinder with a plastic tube and filter funnel, a plot sprayer was devised for spraying small plots with total herbicide volumes of less than a litre.

No other special equipment was required for the herbicide applications used in the field screening experiments.

ii. Data processing and calculation of control parameters

All reported dry matter yields (D.M.) of striga or sorghum were recorded as 'air dry matter'. The material was harvested and dried in the open after the end of the rainy season before weighing.

Unless otherwise stated, all yields, counts and

scores produced in small randomised block experiments were first examined for normality and transformed if necessary. Frequently a log transformation was necessary for striga weight data while the logit transformation occasionally improved the distribution of scores using the scale 0-9. It was normally not found necessary to normalise the data from lattice designs.

A particular problem arose for finding ways of expressing 'striga control' in minilog plots where striga emergence was both sparse and irregular. Not infrequently a large and vigorous striga plant would emerge in the highest dosage section, while the rest of the high dosage end of the plot was completely free. The emergence at the high dosage end might have been due to protection of the striga by sorghum foliage, improved host vigour resulting from earlier striga control (see page 104) or maldistribution of viable striga seeds.

At Samaru where striga emergence was particularly sparse, a striga control parameter was calculated as follows. The minilog plot was divided into 10 equal sections, ranging from the highest to the lowest dosage. If striga emergence occurred on any one section this

was regarded as complete breakdown of control on that section and the plot was awarded a 'failure to control' score, weighted for the dosage applied to the section. The sum of the scores awarded to a main plot was then treated as the main plot negative control value and used in the main plot analysis of variance. The most normally distributed parameter was derived by weighting the score with the logarithm of the dosage applied (+1). Even better distribution was obtained by simply using the position of sub-section to award an integer score. The highest dosage was given a score of 9 and the lowest (to which no herbicide was applied) a score of 0. Hence a main plot on which there was no control of emergence had a score of 45. The parameter '% failure to control' (emergence of striga) was calculated by expressing the treatment means as percentages of the maximum possible failure score of 45.

No fundamental reality is claimed for the parameter. It is simply an easily calculated, normally distributed means of expressing the average performance of a herbicide in minilog plots. If emergence occurs on a high dosage section of the plot it is obviously a more serious breakdown of control than if emergence

occurs on a low dosage section and the parameter expresses this.

(b) Screening of Herbicides for Soil Activity 1967-68

i. 1967 tests

In 1967, 3 well replicated trials of herbicides which appeared to show some selective activity against striga in pot tests, were laid down at Samaru, Kano and Gusau.

The design of the experiments used 8 replicates of 10 minilog plots of the selected herbicides applied pre-emergent. The remaining experimental details were identical to the 1968 trial. (See Appendix 15) Unfortunately striga emergence was so variable on all sites that no clear patterns emerged from the use of the log dilution method.

There were no large or significant treatment differences between mean yields of grain or the various parameters used to assess striga emergence. At Gusau, where the striga emergence was highest, linuron, atrazine and diphenamid appeared to reduce striga emergence without decreasing yield of grain but this was not confirmed by the statistical analysis.

An experiment of the same design, using herbicides

from the phenylacetic, phenylpropionic and benzoic acid groups was also performed at Samaru in 1967. The site of the experiment was very wet, the stand of sorghum was rather variable and the emergence of striga was exceedingly variable. The correlation of grain yield (and sorghum dry matter production) with striga D.M. production was small but positive, indicating that striga production was dependent on sorghum vigour. The correlation was so slight that adjustment of striga weight for sorghum dry matter did not increase the significance of the treatment mean differences.

Using Tukey's D value, it appeared that the control of emergence was significantly better on the chlorfenac treatment than on the 2,4-DB treatment. The grain yield from the 2,4,5-TP treatment was also significantly better than that from the TBA treatments.

Table 9: Results of 'Auxin' type herbicide screening trial at Samaru, 1967

Max. dose# Treatmant	% failure to control	Striga weight lb.ac.	Total sorg. DM 1000 lb/ac	Sorg. grain lb/ac.
2,4-D 1/3	56 a b	70.8	2.91	800 a b
MCPB 1	54 a b	51.7	3.52	878 a b
2,4,5-T 9	59 a b	56.6	2.76	831 a b
Mecoprop 1/3	58 a b	77.4	2.92	644 a b
Chlorfenac 1	30 b	58.2	2.45	687 a b
2,4-DB 1/3	72 a	69.6	2.96	957 a b
2,4-DES 1	61 a b	61.0	2.58	714 a b
MCPA/1	42 a b	57.4	2.83	781 a b
TBA 1/3	49 a b	53.2	2.20	543 b
2,4,5-TP 1	47 a b	61.0	3.46	1016 a
S.E. diff	±12.4	±14.9	±.508	±137.2

Unfortunately, good 'control' of striga emergence was not accompanied by increases in grain yield (except possibly in the case of 2,4,5-TP) and in view of later results, it appears unlikely that the treatment differences shown in Table 9 were caused by real herbicidal control of striga.

ii. 1968 tests

A well replicated minilog trial of nine herbicides which were believed to be active against striga species on the basis of pot test results or manufacturers data sheets was laid down using sorghum seed which was reputed to be from a self fertile dwarf selection, which had been observed to be very susceptible to striga attack (see Chapter 5). (See Appendix 15 for the experimental description) Four dates of application were used:-

Early pre-sowing	25.5.1968
At sorghum thinning	15.6.1968
At sorghum heading	6.9.1968
At 50% striga flower	30.9.1968

The first striga emergence was observed on 14.7.68. The experiment was laid out as a triple square lattice of 36 treatments.

Difficulties were experienced because the sorghum seed was found not to be genetically pure and segregated into distinct components of different heights.

Because of this variability, the best analyses of the treatment effects were made by the calculation of categories for each yard of minilog run, using a categorisation system for sorghum and striga similar to that used in the pot tests. The maturity scores are shown in Table 10.

Table 10: Scores awarded in minilog subsections

State of plant	Sorghum	Striga
Dead	0	0
Missing	1	1
Vegetative	2	2
Heading (sorghum)	3	n.a.
Flowering (striga)	n.a.	3
Bearing mature heads	4	n.a.

A control category was worked out for each yard of run, using the 'highest' state of the sorghum or striga present in the section. The category equalled 4 x (sorghum state) - (striga state). The total categories for each minilog plot were summed and found to

be normally distributed. The data could therefore be analysed by the normal analysis of variance for main-plot (minilog runs) totals.

The results for the 'striga state' and the control category are presented in Tables 11 and 12 respectively.

Table 11 shows that the average striga maturity state on 14.11.1968 in all treatments was a mixture of vegetative (2) and flowering (3) states (see Table 10). The values above 3.00 were due to adjustments for block differences during the lattice analysis. As might be expected, the two later applications had a small effect in reducing the mean striga maturity state slightly at the end of the experiment.

Table 12 indicated that the two later applications also controlled striga less successfully. The third application of herbicide produced a mean category which was significantly lower than the first. Linuron, meditonerb acetate, dicamba and fenac all had a better overall category than 2,4-D. None of the other materials were as good as this standard material. Linuron, dicamba and fenac were listed for further testing when granular formulations were available. Granular meditonerb acetate was already being extensively tested in constant dosage experiments.

Table 11: Log screening test, 1968

Assessment at 14.11.1968

Mean striga maturity states

Name of herbicide	Highest dosage #	Date of herbicide application 25.5.68	15.6.68	6.9.68	30.9.68	Mean
2725 A1	6	2.60	2.68	2.71	2.46	2.61
Bromacil	3	3.08	2.57	2.35	2.46	2.62
2,4,5-TP(K)	6	2.90	3.01	2.93	2.49	2.83
2,4,5-TP(MBE)	6	2.53	3.01	2.68	2.79	2.75
Linuron	6	2.64	3.04	2.64	2.79	2.78
2,4-D	6	3.01	2.13	2.79	3.01	2.74
Meditonerb acetate	6	2.93	2.79	2.71	2.64	2.77
Fenac	3	2.38	2.97	2.49	2.75	2.65
Dicamba	3	2.35	2.57	2.93	2.68	2.63
S.E. diff		±.[illegible]	±.295			±.148
Mean		2.71	2.71	2.69	2.67	2.71
S.E. diff.		±.[illegible]	±.095			

Table 12: Log screening test, 1968

Assessment at 14.11.1968

Striga Control Categories

Name of herbicide	Highest dosage #	Date of herbicide application 25.5.68	15.6.68	6.9.68	30.9.68	Mean
2725 A1	6	8.0	8.1	6.7	10.3	8.28
Bromacil	3	8.4	7.9	9.2	7.5	8.25
2,4,5-TP(K)	6	8.6	9.7	7.7	7.3	8.32
2,4,5-TP(MBE)	6	7.1	8.2	10.3	7.4	8.25
Linuron	6	13.5	10.3	7.7	11.7	10.80
2,4-D	6	11.0	10.6	6.1	6.9	8.65
Meditonerb acetate	6	11.9	7.9	9.4	11.4	10.15
Fenac	3	10.6	10.3	8.6	8.0	9.38
Dicamba	3	9.8	12.1	7.7	9.7	9.82
S.E. diff			±1.83			±.918
Mean		9.88 a	9.46ab	8.16 b	8.91ab	9.10
S.E. diff.			±.595			

(c) Screening Herbicides for Contact Activity, 1967-68

i. 1967 test

In 1967 a heavy natural infestation was observed in some dwarf hybrid sorghum breeding lines at Samaru and a number of herbicides were screened for their contact activity against striga. The treatments in the one effective replicate were applied on 21st September, with the minilog sprayer to logarithmic dilution plots of 10 x 1 yd. (see experimental proposal in Appendix 13).

Treatments and results

The most important effects to be observed at this stage of sorghum growth were (a) inhibition of striga flowering and (b) effect on sorghum yield. Because the experiment was only a single effective replicate, it was not possible to give a standard error for any result and because each plot was a single breeding line, it was only possible to compare the effect of rates of a herbicide on yield. It was impossible to compare the effect of one herbicide with another in its effect on sorghum yield. The sign of the regression coefficient of yield on dosage is therefore quoted:

The results in Table 13 showed that a wide range

of herbicides was contact active against striga at very low dosages per sprayed acre. The activity of materials like ametryne, linuron and chloruxuron, which are well tolerated by crops normally grown in association with sorghum in farmers' fields, was particularly interesting.

Some of the herbicides inhibited the flowering of the striga regrowth as well as killing the emerged striga but the dosage required was much higher. The most economical use of herbicide therefore would be to kill the emerging striga by repeated spot spraying with the dosage required to kill by contact.

Conclusion

4. Striga control using repeated spot spraying of emerged striga was therefore potentially possible in crop mixtures with low dosages of herbicide.

Table 13: Contact Activity screening test, 1967

Herbicide /highest dosage #	Dosage # killing striga by contact	Dosage # inhibiting flowering at 33 days	Dosage # inhibiting flowering at 50 days	Regression of yield of sorghum grain on dosage
2,4,5-T/9	0.2	1.5	4.0	-ve
Monuron/3	0.3	0.5	1.3	-ve
2,4,5-TP/K/3	0.5	1.3	1.6	+ve
Diquat/0.75	0.2	0.3	0.5	-ve
Ametryne/3	0.2	1.1	1.8	-ve
Cypromid/3	0.4	1.8	1.8	-ve
Mecoprop/3	0.4	1.8	1.8	-ve
Linuron/3	0.3	0.8	1.8	-ve
Chloroxuron/3	0.3	1.8	2.0	-ve*
2,4-D (amine)/3	0.2	1.0	2.0	+ve
Propanil/3	1.9	1.6	2.0	+ve
MCPB/3	0.7	1.6	2.3	+ve
Fenac/3	0.3	1.0	2.3	+ve
Atrazine/3	0.2	2.3	2.3	+ve**
MCPA/3	0.7	1.6	2.3	-ve
Amitrole T/3	0.5	0.8	2.3	-ve
Paraquat/0.75	0.1	0.4	0.6	+ve
Morfamquat/0.75	None	0.4	0.6	-ve

Table 13 (contd): Contact Activity screening test, 1967

Herbicide /highest dosage #	Dosage # killing striga by contact	Dosage # inhibiting flowering at 33 days	50 days	Regression of yield of sorghum grain on dosage
OCS-21944/3	0.2	1.8	None	+ve
Flumeteron/3	2.6	1.8	None	+ve
2,4-D B/3	None	None	None	+ve
Metabromuron/3	0.7	None	None	+ve
Simazine/3	1.3	None	None	+ve**
Propachlor/3	0.2	None	None	?
Propazine/3	None	None	None	-ve

ii. 1968 test

A larger replicated trial was laid down in 1968 at Samaru (see experimental description in Appendix 16). A simple lattice design was used.

The same sorghum seed was used in this experiment as was used in the soil activity screening test, 1968 (see page 126). As a result of the variability caused by the use of this seed, no reliable grain yield or sorghum dry matter production data were obtained.

Emergence of striga was also scanty and irregular so that a simple observation of the dosage controlling striga on each plot could not be made. Assessment of results was therefore made by subjective scores.

The sequence of herbicide applications and scores was as follows:-

Date	Operation
3.9.1968	First herbicide application
5.9.1968	First subjective assessment by ranking plots within subplots. The ranks were converted to rankits before statistical analysis
9.10.1968	% control of striga flowering recorded (see description of method on page 121)
24.10.1968	Second herbicide application
26.10.1968	Second subjective assessment
8.11.1968	% control of striga flowering recorded again.

Table 14: **Results of contact screening trial 1968**

Name of herbicide /maximum dosage #	Subjective rankings for striga cont. 5/9	26/10	5/11	% control of striga flowering 9/10	8/11	Total striga emergence 1000s/ac.	Striga dry weight lb/ac.
D263/3	6	1	1	23	5	32.7	146.2
*Dicamba/3	1	2	2	25	30	26.8	86.6
R7465/3	8	6	2	36	5	61.8	150.7
D497/3	13	2	2	42	25	10.1	32.5
Bromacil/1	6	3	3	24	10	23.4	102.8
**Diquat/0.75	(7)	6	3	19	20	34.9	110.7
Lenacil/1	4	3	3	16	5	68.3	206.6
TCA/3	9	9	4	38	20	74.6	131.5
Diuron/3	2	6	5	4	0	114.5	174.5
*Chloramben/3	1	6	6	12	0	102.9	224.0
**C6313 + wetter/3	1	4	6	40	10	31.8	135.2
Chlorbufam/3	(3)	5	6	44	30	12.5	61.9
**Morfamquat/0.75	(7)	8	6	40	0	128.4	201.3

Results of contact screening trial 1968 (contd)

Name of herbicide /maximum dosage #	Subjective rankings for striga cont. 5/9	26/10	5/11	% control of striga flowering 9/10	8/11	Total striga emergence 1000s/ac.	Striga dry weight lb/ac.
Chlorpropham/3	9	8	6	17	0	104.3	214.2
Dalapon/3	11	6	6	12	00	59.2	237.3
**C10725/3	11	6	6	12	0	49.8	132.3
2,4-DES/3	?	6	6	52	25	1.7	53.9
**Urea + wetter/170	4	5	7	27	5	31.6	129.1
Asulam/3	9	6	7	17	20	41.6	158.4
**Chlorthal/3	13	7	7	22	0	65.0	169.1
Chloroxuron + wetter/3	11	11	7	29	20	100.3	184.1
**C9122/3	10	8	8	31	5	26.3	64.5
Azak/3	5	8	8	24	0	50.9	130.8
Difenamid/3	9	6	8	34	5	75.8	208.4
Buturon/3	12	2	9	36	10	32.6	83.1

Results of contact screening trial 1968 (contd.)

Name of herbicide /maximum dosage #	Subjective rankings for striga cont. 5/9	26/10	5/11	% control of striga flowering 9/10	8/11	Total striga emergence 1000s/ac.	Striga dry weight lb/ac.
*2725 A1/3	3	10	10	30	5	22.2	85.8
Noruron/3	7	10	10	16	20	71.5	137.7
***C6989/3	2	9	11	39	0	96.9	167.1
Monolinuron/3	6	7	11	33	0	111.9	137.5
C3470/3	10	11	11	17	0	128.0	165.5

* Outstanding early 'knockdown' effect

** Visible contact activity on flowering striga

*** Good contact (early) activity

(x) Striga emergence incomplete. Estimated value.

The results given in Table 14 show changes in the relative performances of the herbicides. The treatments are listed in the rank of the assessment on 5th November but there is doubt as to whether this represents the true order of merit.

Much of the variation in striga emergence was undoubtedly due to site differences not compensated for by the lattice design.

It was impossible to make an assessment of the 2,4-DES treatment on 5th September because no striga had emerged on either plot of the treatment at this date. Subsequent emergence on this treatment was sparse, almost certainly because the infestation was low on these plots.

Treatments giving rapid contact activity

Chloramben, dicamba, 2725 A1 and C6989 all gave rapid contact activity and dicamba continued to receive high rankings throughout the season.

Other treatments giving visible contact activity

Diquat, morfamquat and C10725 were too toxic to be recommended for use by hand farmers but gave good control.

C6313 was slowly contact active and is reported

by the manufacturers to be well tolerated by sorghum and will receive further testing.

C9122 and noruron were active only against immature striga.

Urea + non-ionic wetter was moderately active at both applications.

The contact activity shown by chlorthal was completely unexpected because this material is reputed to be mainly soil active.

Active materials tolerated by other crops

Chloramben, noruron and urea were the only materials expected to be tolerated by groundnuts and other mixed crops which were also not poisonous to man.

(d) Combined technique screening for contact activity and soil activity in the same observation plot, 1969

i. Revised basis for screening tests

By 1969, several herbicides were known to be contact active against striga at a dosage of 0.1 #. New herbicides were therefore screened for contact activity at or below this dosage.

ii. The 1969 technique, Samaru

The detailed technique used in 1969 was as follows. A large area of sorghum (Short Kaura variety) was sown

and infested with striga. As striga emergence occurred plots were laid out wherever the emergence was satisfactory. The plots were 10 x 2 yd. in dimensions and markers were placed at 6 yd. and 9 yd. from the high dosage end of the plot. A minilog application was then made with a starting dosage arranged to give a dosage of 0.1 # at the 6 yd. marker. The run was continued up to the 9 yd. marker. The last yard of the plot was left for observations on the changes in the untreated striga population.

One week after the first application of herbicide, the plot was examined. If any 'green and turgid' striga plants apparently unaffected by herbicide were found to be still present in the 0-6 yd. area of the plot, the herbicide could be regarded as 'not contact active' at a dosage of 0.1 # . As there was a chance that the striga had been shielded from the spray by sorghum stems or drooping leaves, the herbicide applications were repeated twice at weekly intervals unless complete control had been established in the 0-6 yd. area after the second application.

This gave a maximum dosage of 11.49 # , reducing to 0.3 # at the 6 yd. marker. Experience had

indicated that any practically useful activity was unlikely to be found outside this range of dosages.

If contact activity had still not been observed one week after the third application, the emerged striga was killed by spot spraying with paraquat. The plot was then observed for control of striga emergence throughout the remainder of the season.

iii. Observations

In addition to the observations which were necessary to determine the herbicide regime, observations on herbicide activity were made every week. The following observations were recorded in feet from the high dosage end of the plot.

1. Range of dosage toxic to sorghum.
2. Range of dosage giving complete control of emerged striga.
3. Range of dosage giving general weed control.

iv. Results

The voluminous results of this trial are given in Appendix 6 and only a few outstanding results are discussed here.

C6989 was applied in a new formulation. The 30% e.c. formulation used proved markedly more contact

active than the 36% e.c. applied previously. The first application on 26.8.1969 killed young green and turgid striga at a dosage of 0.016 #. At the beginning of the fourth week, new emergence occurred in the zone which had received 2.0 # and a second application was made but failed to control new emergences at a dosage of 4.0 #. A week later therefore, the third application was necessary. Dosages which failed to control all new emergences thereafter rose to 7.6 # by the eighth week.

All of the emerged striga on the high dosages died a week or so after emergence and striga was only able to continue to grow at dosages of 3.3 # and less. There is no doubt therefore that this formulation of C6989 is very contact active against striga with some definite soil activity at rather high dosages. At the growth stage when treatments started (just before flag leaf emerged) sorghum tolerated the maximum dosage of 11.5 # without any visible toxicity symptoms.

None of the other herbicides showed any marked contact activity but two incorporated herbicides gave very striking control of emergence. With these materials, the observation for contact activity was

omitted and the plot was shallowly cultivated with a hoe immediately after the application.

Table 15: Performance of incorporated herbicides

Complete control of striga emergence

Name of herbicide	Period of complete control	Dosage #
Nitralin	10 weeks	0.027
Triallate	6 weeks	0.027

The only material causing marked toxicity symptoms to the sorghum was bromacil. 2.6 lb. caused marked necrosis and eventual death but 3.3 lb. were required to control the striga. Bromacil may possibly have a use pre-emergent to sorghum (see pot test results Appendix 4.11) but it is clearly not selective when used as a contact application.

v. Discussion of the 1969 test method

If further initial screening of herbicides is required in future, it is anticipated that this technique or a development of it will be used in preference to pot tests. There are certain obvious weaknesses. No sorghum yield data are recorded; in this respect the field screen is less informative than pot tests.

It is considered however that yield data from poorly replicated field screening tests may be misleading and invariably needs to be confirmed by well replicated experiments at constant dosage at a number of sites.

The herbicide applications start late in the life of the crop after striga emergence has occurred. Hence the soil activity observed is not strictly comparable with that of applications made pre-emergent to striga. Nevertheless, if a herbicide is soil active against striga regenerating from the underground portions left after hand pulling or paraquat treatment, it is almost certain to be active against germinating striga seedlings. The converse is not necessarily true and as both types of herbicidal activity are desirable in practice, the more stringent test is to be preferred.

The great advantage of the 1969 method is that it guarantees the presence of striga during the test. It also requires only the objective recording of the presence or absence of emerged striga, which permits the routine weekly observations to be taken by less skilled staff than were required by previous techniques.

A further less stringent test of activity which

should be made in future tests is the weekly record of the highest dosage at which striga flowering occurs. In several treatments, emerged striga grew slowly and failed to set seed at dosages of about 1 #.

Conclusion

5. Selective activity against Striga hermontheca occurs in many chemical groups of herbicides.

S T A G E I I

Evaluation in the environment

CHAPTERS 8 - 9

CHAPTER 8

CONTROL OF STRIGA BY SOIL APPLIED TREATMENTS

(a) 'High' fertiliser nitrogen applications

i. 1967, N rates experiment at Samaru

In 1967 a preliminary experiment on the effects of high rates of fertiliser nitrogen in suppressing striga emergence was conducted, using the variety Short Kaura at standard spacing of 3 x 1½ ft.

The experiment was laid out as a double latin square using four rates of fertiliser nitrogen (see Appendix 11 for full experimental description). To avoid lodging caused by unbalanced nutrition, the nitrogen applications were balanced by equivalent applications of phosphate fertiliser. The fertilisers were applied when the sorghum was thinned.

Table 16: Results of high fertiliser nitrogen applications at harvest 1967

Treatment as lb fertiliser N/ac	Weight of striga (lb/ac) Untransformed	Retransformed *from log(x+1)	Number of striga 1000/ac	Weight of grain lb/ac
Untreated	9.1	5.6 a b	1.36	3090
23	13.1	6.8 a	2.12	3210
46	5.6	3.1 a b	0.89	3080
69	2.9	1.9 b	0.64	3090
S.E. diff.	±4.76		±.544	±484

* No standard error is applicable to the retransformed means.

Uniformly high yields of grain were obtained at all levels of fertiliser nitrogen application. Though there were no significant differences between treatments, there was a higher yield at the lowest nitrogen application rate. The effect of the two highest nitrogen applications was to markedly increase the size and vegetative vigour of the sorghum plant. Unfortunately, dry matter yields were not recorded but observations indicated that dry matter production was still increasing at the highest rate of application. Striga emergence and dry matter production was at a very low

level but it was interesting that the first increment of nitrogen produced an increase in striga, whereas further increments progressively reduced it below the level of the untreated control. Inspection of the striga weight data revealed that the distribution was lognormal with a few comparatively high values inflating the means of all treatments. After transformation to log (x+1) it was found that there were significant differences between treatments. The 23 lb rate of fertiliser nitrogen gave a yield of striga which was significantly higher than that produced by the 69 lb rate. The linear component of the nitrogen rates showed a significant depression in striga population with increasing applications of nitrogen.

ii. 1968 N rates experiment at Samaru

The 1967 experiment was repeated on the same site, again using the variety Short Kaura but doubling the rates of nitrogen fertiliser and balancing phosphate (see experimental description in Appendix 12).

Table 17: Results of high fertiliser nitrogen applications at harvest 1968

Treatment as lb fertiliser N/ac	Weight of striga lb/ac	Number of striga 1000/ac	Sorghum D.M. 1000 lb /ac.	Sorghum grain lb/ac
Untreated	96	12.95	5.0 c	813 b
46	110	23.02	7.4 b	924 b
92	83	13.93	9.4 a	1226 a b
138	42	7.93	10.4 a	1381 a
S.E. diff.	±26.2	±5.84	±0.65	±106

The pattern of sorghum grain yield and dry matter was of continuous increases with increasing fertiliser rates, whereas both total striga weight and number were at a maximum at the intermediate rates.

The size and significance of the factorial components of the fertiliser are presented in Table 18.

Table 18: Results of high fertiliser nitrogen applications, 1968

Factorial components of the treatments

Treatment component	Weight of striga lb/ac	Number of striga 1000/ac	Sorghum D.M. 1000 lb /ac.	Sorghum grain lb/ac
Linear	-40.5	-7.05	7.4***	435*
Quadratic	-27.5	-8.03	-1.4**	+22
Cubic	-13.5	2.04	3.4***	133
S.E.	±18.5	±4.14	±0.44	±75.2

The linear response to increasing nitrogen was to significantly depress the weight of striga dry matter and significantly increase the grain yield.

There was no correlation between grain yields and striga production if the design of the experiment was taken into account but if all variances, except treatments, were pooled, there was a large and significant negative correlation. It is, therefore, concluded that the design of the experiment was efficient in averaging out the effects of chance variations in striga occurrence.

The marked reduction in striga occurrence at the

higher nitrogen levels was further examined by correlating the yield of striga with the total dry matter production of the sorghum. If the correlation at each fertiliser level proved positive it could be deduced that the reduction was not primarily due to competition for light energy from the sorghum and that the treatment effects were due to some other factor. If the correlation proved to be negative, the relationship could be due either to the effect of the striga in reducing dry matter production of the sorghum by parasitism or the effect of the sorghum in reducing light penetration as the sorghum dry matter (and hence the cover) increased. Table 19 shows that the relation was not consistent at all fertiliser levels.

Table 19: Covariance of striga with sorghum dry matter production at four levels of fertiliser nitrogen

Nitrogen application, lb/ac	Regression coefficients: Sorghum D.M /striga D.M	Striga D.M /sorghum D.M	Variance ratio
Untreated	-15.2	-.0184	2.34
46	-10.3	-.0150	1.10
92	-24.9	-.0157	3.84
138	+ .032	+.00009	0

At the highest level there was no detectable relationship, whereas at all the lower levels the relationship was negative. The variation in sorghum dry matter was least and the variation in the striga dry matter was greatest at the highest level of fertiliser application. This is at least consonant with a situation where sorghum plants in mutual competition achieved a complete uniform plant cover and where striga growth varied according to the natural infestation rather than some factor controlled by sorghum growth.

iii. 1969 N rates experiment at Samaru

The 1968 experiment was repeated on the same site, using the same fertiliser applications but replacing the sorghum variety Short Kaura with a new dwarf variety B 2123. The variety was sown at three foot spacing between rows and six inches between stands. This gave a theoretical population very close to that recommended for this variety at square spacing and also ensured that the inter-rows would never be covered by the dwarf sorghum. The experiment therefore measured the effect of fertiliser nitrogen rates on the striga without the complications caused by variations in the amount of light available to the striga.

Table 20: Results of high fertiliser nitrogen applications at harvest 1969

Treatment as lb fertiliser N/ac	Weight of striga lb/ac	Number of striga 1000/ac	Sorghum D.M. 1000 lb /ac.	Sorghum grain lb/ac
Untreated	125	104	2.35 b	123
46	184	118	3.15 b	131
92	164	111	4.50 a	234
138	155	126	3.20 a b	183
S.E. diff.	±34.6	±29.8	±.524	±62.5

The weight of striga remaining at harvest was higher than in previous seasons and as in 1968, the greatest weight occurred on the treatment receiving 46 lb. of fertiliser nitrogen. The numbers of striga stems counted differed very little between treatments. None of the treatment differences were statistically significant. Sorghum grain yields and dry matter yields were highest in the treatment receiving 92 lb. of fertiliser N. The linear and quadratic components of the sorghum dry matter response curve were significant at P=0.05. The reason for this real reduction in growth and vigour at the highest N rate is not known

and needs confirmation at other sites. On this site it might be due to the removal of some essential nutrient by the previous cropping in 1967 and 1968.

The other correlations were negligible and confirm that with variety B 2123, sown at 3 ft. by 6 inches, there is no general negative correlation between striga growth and sorghum growth.

Table 21: Results of high fertiliser nitrogen applications 1969

Covariance of striga with sorghum dry matter production at four levels of fertiliser nitrogen

Nitrogen application lb/ac	Sorghum D.M. /striga D.M.	Striga D.M./ sorghum D.M.	Variance ratio
Untreated	1.97	0.00655	0.078
46	-2.11	-.0196	0.259
92	5.48	0.0114	0.401
138	9.14	0.0553	6.16*

Summary

In tall sole crop sorghum the highest rates of application of fertiliser N in 1967 and 1968 reduced striga. The lowest application rate increased it. In dwarf sole crop sorghum in 1969, striga was increased at all levels of fertiliser N application.

Conclusion

6. Three years' results from successive crops of sorghum on the same site support but do not prove the hypothesis that the effect of high fertiliser nitrogen in reducing striga infestation is mainly due to the interception of light energy by the increased crop cover.

(b) 2,4-D Granules Series 1967-68

i. 2,4-D granules experimental series, 1967

At the beginning of 1967 the only herbicide active against striga which was available in granular formulation was 2,4-D. A proprietary formulation containing 20 per cent 2,4-D, which was originally intended for use in flood rice, was obtained in sufficient quantity to perform a series of eight experiments at different centres. (See experimental description in Appendix 8) The experiments consisted of 2 replicates of 9 plots each. The experimental design was a 2^3 factorial, with an additional control plot per replicate. Striga seed which was collected at Samaru in 1966 was supplied to infest the experimental sites. Results were obtained from 6 centres.

The effects on grain yield are shown in Table 22.

Table 22: 2,4-D granules experiments, 1967

Treatments (applications per acre)	Symbol
20% 2,4-D granules broadcast at 1 #	Dg
1 cwt of 24-16-0 compound fertiliser broadcast	F
All treatments applied early	E
All treatments applied at thinning	T

Results

Parameter	Grain yield	Sorghum D.M.	Striga D.M.
Units	lb/ac.	1000 lb/ac.	lb/ac.
No. of experiments	6	5	4
Treatment			
Untreated	1371 a b	5.85	16.50
Dg E	1169 c	5.08	9.97
F E	1320 b	5.77	4.06
Dg F E	1487 a	6.32	13.93
Dg T	1356 a b	5.92	9.17
F T	1356 a b	6.51	7.92
Dg F T	1285 b c	6.16	9.10
S.E.	±45.7	±0.570	±11.76

The mean effect of 2,4-D granules applied pre-sowing was to depress grain yield significantly in the absence of fertiliser and to increase it in the presence of fertiliser. The increase would not have been economic at current sorghum grain prices. The applications at thinning time had smaller effects.

2,4-D granules applied pre-sowing without fertiliser depressed sorghum dry matter production below the level of the untreated control. Fertiliser effects were small.

Though there were fairly consistent trends in striga dry matter production, the variability of the data was high, the error proved to be heterogenous and there were large site x treatment interactions. The data values were therefore converted to logarithms and re-analysed but there was no improvement in the separation of the treatment means.

The striga infestations were generally rather low at all the centres and probably had little effect on sorghum production.

There were no large correlations between sorghum grain, sorghum dry matter and striga infestation.

ii. Micro-granular formulations of 2,4-D group herbicides 1968

Samaru

To obtain further information about best times of application of herbicides against striga, an experiment was laid down using four times of application of three granular formulations of 2,4-D group materials. In addition, factorial combinations of 69 lb. of fertiliser nitrogen and 46 lb. of fertiliser phosphorus were applied as a separate set of treatments.

The experiment was laid down as a simple partially balanced lattice, with sixteen treatments.

The experimental variety was Short Kaura and each stand of sorghum was infested at sowing time with a 'pinch' of striga trash "large enough to cover a penny".

The experimentsl materials used were:-

	Symbol
2,4-D 20% granules (Acqua Kleen), a proprietary formulation of low-volatile 2,4-D ester intended for weed control in rice	Dg
2,4-D/MCPA 18% microgranules (Granulox A) intended for contact applications against broadleaved weeds in temperate cereals	A

	Symbol
2,4-D/MCPA/picloram 18% micro-granules (Granulox B) identical to treatment A except for the addition of picloram. All herbicides applied at 1 #	B

The times of application were defined as follows:-

'Early' Applied pre-sowing and incorporated during the final seed-bed preparation (May)	E
'Thinning' Broadcast at sorghum thinning time (June/July)	T
'Sorghum heading' Broadcast when the first sorghum head emerged from the flag leaf (July/August)	S
'At first striga flower' In practice this coincided with the S treatment date. The application was therefore deferred until approximately 50% of the emerged striga had flowered and then applied as a contact dust (August/September)	F1

For further experimental details see Appendix 10.

Results

The sorghum populations surviving at harvest were very low compared with the sown stand of 9.7 thousannd per acre. The very heavy striga attack on unmanured land undoubtedly killed many sorghum plants. Fertiliser nitrogen and phosphate reduced the losses. 2,4-D herbicides also reduced losses slightly.

The 'Dg' and 'A' treatments both gave small increases in grain yield and small decreases in striga. The 'B' treatment was much less successful. The only difference between 'A' and 'B' is the small amount of picloram in the latters.

The two later applications gave higher yields of grain than the two earlier applications. The last 'Fl' treatment also considerably reduced the amount of striga.

High nitrogen alone or in the presence of phosphate gave proportionately large yield increases but failed to suppress striga.

In the experiment as a whole, the poor cover resulting from the sparse sorghum stand surviving to the end of the experiment probably permitted unrestricted light energy to reach the striga plants. This

probably explains why the last F1 herbicide application reduced striga growth more than earlier treatments because it was applied at the point where the natural control from crop cover was least effective.

The results indicate that the later applications of herbicide increased grain yields and reduced striga infestation in contrast to the results obtained by Last (1961) in the Sudan but it is also possible that part of the effect was due to the early applications of the 2,4-D herbicides reducing the early vigour of the sorghum and permitting the emerging striga to establish at higher light intensities. This hypothesis is supported by the fact that the two earliest applications have yields of the same order as the untreated control. It was also supported by the fact that treatment 'B', which contained the persistent herbicide picloram, was slightly but consistently less productive than the other two materials.

The recommended local variety of sorghum was sown and each stand was infested with striga by putting a 'pinch' of striga trash into each sowing hole.

See Appendix 9 for remaining experimental details.

Table 23: Results of micro-granular formulations of 2,4-D group herbicides experiment at Samaru

Parameter units	Sorghum grain lb/ac.	Striga D.M. lb/ac.	Sorghum count 1000/ac.
Treatments			
Untreated	282	189	5.04
Striga control herbicides			
Dg	344	109	5.98
A	376	125	5.89
B	289	166	5.41
S.E. diff.	±62.0	±54	±.522
Times of application			
15.5.1968 (E)	264	197	5.98
12.6.1968 (T)	284	115	5.26
22.8.1968 (S)	392	172	5.94
14.10.1968 (M)	405	40	5.87
S.E. diff.	±72.5	±80	±.452
Striga control fertilisers			
69 lb N/ac.	618	255	5.98
49 lb P/ac.	343	217	6.72
N + P	739	297	8.60
S.E. diff.	±104	±136	±.904

iii. Micro-granular formulations of 2,4-D group herbicides, 1968

States experiments

A series of experiments using the same materials as at Samaru but with a simpler experimental design were also performed at five sites in the States.

The experimental design was a 2 x 6 factorial in 2 replicates of 12 plots.

Fertiliser treatments	Symbol
23.5 lb N + 16 lb P applied in a 21-14-0 compound fertiliser placed adjacent to the sorghum seed at sowing	F
Absence	-

Striga control treatments

Untreated	-
2,4-D 20% granules at 1 # broadcast before sowing	DgE
" " " " " at thinning	DgT
2,4-D/MCPA/picloram 18% micro-granules at 1 # broadcast at thinning	BT
2,4-D/MCPA 18% micro-granules at 1 # dusted on to emerged striga at first striga flower	AS
70 lb N + 47 lb P as 21-14-0 compound broadcast at thinning	NT

Results

Table 24: Results of micro-granular formulations of 2,4-D group herbicides (States experiments) 1968

Parameter	Grain Sorghum D.M	Striga D.M
Units	lb/ac.	1000 lb/ac,	lb/ac.
No. of experiments	5	4	3
Treatments			
Untreated	464 b	4.2 b	81.5
Striga Control herbicides			
DgE	504 a b	3.3 b	65.0
DgT	625 a b	3.9 b	53.8
BT	635 a b	4.2 b	68.7
AS	626 a b	4.4 b	127.2
Striga control fertiliser			
NT .	754 a	7.3 a	54.6
S.E. diff.	±88	±0.62	±27.00
Manurial fertiliser (applied factorially)			
Absence	471 d	3.9	65.2
P	690 c	5.2	83.2
S.E. diff.	±105	±.63	±15.30

Both the striga control fertiliser (NT) and the manurial fertiliser (F) gave significant increases in grain yield. Both treatments gave increases in sorghum dry matter but whereas the F treatment increased the amount of striga, the NT treatment applied at thinning time, with a much heavier application rate, reduced the amount of striga. This treatment would be expected to give better foliar cover and hence greater competition with the striga.

The herbicide applications all gave non-significant increases in yield and the three earliest applications decreased both sorghum dry matter and striga. The considerable increase in striga with the AS treatment (a contact application) was surprising because all of the logbooks describe the rapid and effective control of striga obtained with this treatment. It seems likely that the increased striga weight included dead striga stalks, which were hard and woody and that considerable re-emergence occurred after the application. The grain yield was comparable with that obtained with earlier treatments.

2,4-D granules applied pre-sowing (DgE) reduced sorghum dry matter production. Three logbooks reported

early yellowing of the sorghum leaves. Heavy losses in stand in this treatment were observed at one centre.

Conclusions

7. Soil applied striga control treatments of fertiliser or 2,4-D granules gave increases in yield of grain but no effective reduction of striga. Pre-sowing was not the best time of application for 2,4-D.

(c) Granular herbicide experiments

i. Samaru, 1968

By the start of the 1968 season a number of granular herbicides believed to possess selective activity against striga had been received. A series of trials was laid down at Samaru and in the northern states. The trial at Samaru was more complicated and comprised seven herbicide treatments applied at two different times, plus two additional treatments. The sixteen treatments thus obtained were laid out in a partially balanced simple lattice design.

Experimental treatments

Striga control treatments	Symbol
Atrazine at 3 # as 4% granules	Atg
Chlorthiamid at 1 # as 7.5% granules	Ch
Chloramben at 1 # as 10% granules	Cm

Striga control treatments (contd)	Symbol
C 6989 at 1 # as 5% granules	C
Fenuron at 1 # as 25% granules	Fen
Prometryne at 1 # as 4% granules	Pr
Meditonerb acetate at 3 # as 6% granules	Me
Times of application	
Pre-sowing (16.5.1968)	E
At thinning (12.6.1968)	T
Additional treatments	
Handweeding of striga every week	H
Untreated	-

Crop: Sorghum variety 'Short Kaura', sown at 3' x 2' and thinned to 2 plants per stand = 14,500/ac.

Application of treatments

At both times of application, the herbicides were broadcast on the soil surface and were incidentally incorporated by the hand cultivations given to the plots at sowing and thinning.

One plot of the prometryne treatment 'applied early', accidentally received 10 # of the wettable powder formulation. This has been treated as a missing plot in all statistical analyses.

See Appendix 18 for remaining experimental details.

Results

Table 25: Granular herbicides, Samaru 1968

Sorghum grain yield, lb/acre

Time of application	Pre-sowing	Thinning	Means
Herbicide			
Atrazine	708	854	781
Chlorthiamid	629	566	598
Chloramben	878	625	752
C6989	697	740	718
Fenuron	455	531	493
Prometryne	0	637	318
Meditonerb acetate	678	427	552
Handpulling	609		
Untreated	223		
S.E. diff.	±269		±190
Means	577	625	
S.E. diff.	±110		

Atrazine, chlorthiamid, chloramben, C6989 and meditonerb acetate all gave adjusted yields comparable to or better than that produced by intensive hand pulling. Atrazine, chloramben and C6989 gave yield increases over the untreated control treatment, which

were almost certainly economic at current (1969) grain prices.

The estimated yield of prometryne applied pre-sowing was based on one plot only. The unadjusted yield of this plot was 268 lb/ac.

Fenuron and prometryne were included in this experiment because granular formulations were available and other materials indicated to be selective by pot tests and field screening tests had not been received in time. The mediocre performance of these materials confirmed earlier indications from the screening procedure.

The striga attack was so intense that one 'untreated' plot produced no grain at all. An adjacent plot in another sub-block produced over 900 lb grain per acre with 3 # of atrazine.

Table 26: Granular herbicides, Samaru 1968

Striga weight lb/ac. at harvest

Time of application	Pre-sowing	Thinning	Means
Herbicide			
Atrazine	158	117	138
Chlorthiamid	165	136	150
Chloramben	178	241	210
C6989	387	107	247
Fenuron	229	160	194
Prometryne	505	222	363
Meditonerb acetate	75	196	136
Handpulling (average per week)	214		
Untreated	312		
S.E. diff.	±102.4		±72.4
Means	242	168	
S.E. diff.	± 38.6		
Handpulling (total)	3140 ≅ 760,000 striga emergences/acre.		

The herbicide treatments did not effectively control striga emergence and none of the treatments were significantly different. The most striking result in this table was the effect of handpulling all striga each week. Well over one ton of air-dry striga was

removed during the season per acre, giving a yield increase of 376 lb. of grain over the untreated control. Even this very vigorous mechanical control failed to increase grain yield to the level of the highest yielding herbicide materials. The enormous increase in striga emergence stimulated by the handpulling would undoubtedly discourage any farmer from attempting this intensity of handpulling.

Table 27: Granular herbicides, Samaru 1968

Total sorghum dry matter 1000 lb/ac.

Time of application	Pre-sowing	Thinning	Means
Herbicide			
Atrazine	4.26	3.87	4.06
Chlorthiamid	4.04	2.72	3.38
Chloramben	4.78	2.88	3.83
C6989	4.67	3.85	4.26
Fenuron	2.37	3.62	3.00
Prometryne	0	3.02	1.51
Meditonerb acetate	3.62	1.38	2.50
Handpulling weekly	3.28		
Untreated	2.00		
S.E. diff.	±1.581		±1.118
Means	3.39	3.05	
S.E. diff.	±0.597		

Except for prometryne applied early, there were no marked effects on sorghum dry matter production and differences in grain production did not correspond closely with the dry matter production.

This single experiment demonstrated that single applications of granular residual herbicides could increase grain yield under severe striga attack but could not prevent striga emergence.

ii. Residues experiment, Samaru 1969

The site of the previous experiment was used to measure herbicide residue effects on cotton, groundnuts and dwarf sorghum, all grown without fertiliser. The net plots of the 1968 experiment (6 yd. x 6 yd.) each contained two rows of each crop of which a 5 yd. length was harvested, giving a net harvested area for each crop in each plot of $\frac{1}{242}$ ac. The total above ground dry matter production of the cotton, groundnuts and sorghum was harvested as soon as the groundnuts were ready for lifting. The kernel yield of the groundnuts was also determined.

1969 was the first season in which a dwarf sorghum variety was available for general field experimental use so that little was known about its behaviour under

very heavy striga attack.

The very low level of sorghum dry matter production was mainly due to this use of a dwarf sorghum variety, grown at 3' x 6" spacing without fertiliser.

Results

Table 28: Granular herbicides, Samaru 1968

Residual crops 1969

Effect of herbicide residues: Yields in lb/ac.

Crops harvested when groundnuts were lifted.

Crop / Herbicide	G.N. Tot. dry matter	G.N. Kernels	Cotton Tot.dry matter	Sorghum Tot.dry matter	Striga Tot.dry matter
Atrazine	2301	433	771	847	40.6 a b
Chlorthiamid	2045	467	891	676	39.1 a b
Chloramben	2354	361	786	640	29.1 b
C6989	2602	490	1149	698	85.7 a
Fenuron	2586	387	1167	641	86.5 a
Prometryne	2337	340	889	338	33.9 b
Meditonerb acetate	1970	366	1073	655	12.5 b
No herbicide	2004	238	894	706	21.9 b
S.E. diff.	±490	±117.4	±219	±194	±13.39

Significantly more striga grew on the C6989 and fenuron treatments than on the 'No herbicide' treatment.

All of the herbicide treatments except meditonerb acetate produced more striga than the 'No herbicide' treatment. There was a substantial negative correlation between the 1968 striga dry matter production and the 1969 striga dry matter production. The best correlation with the cube root of the production was significant at P= 0.1. This suggests that quite apart from herbicide treatment effects, plots which grew most striga in 1968 produced least in 1969. As the striga dry matter was completely removed from the site in 1968, it seems possible that an essential nutrient for striga growth might have been removed with it.

Neither groundnuts nor cotton total dry matter were significantly depressed by any herbicide residues. All herbicide residual treatments gave yields similar to the 'No herbicide' control yields.

Conclusion

8. At Samaru, residues of granular striga control herbicides were not harmful to following crops.

iii. States experiments, 1968

The 8 experiments of simple 5 x 2 factorial design (twice replicated) which were also performed in 1968

at various states experimental centres had the following treatments:-

	Symbol
<u>Fertiliser treatments</u>	
Nil	-
21-14-0 compound fertiliser at 1 cwt/acre placed at sowing	F
<u>Striga control treatments</u>	
Nil	-
21-14-0 compound fertiliser at 3 cwt/acre broadcast at thinning (High N)	N
Atrazine 4% granules at 3 # broadcast at thinning	Atg
Meditonerb acetate 6% granules 3 # broadcast at thinning	Me
Chlorthiamid 7½% granules 1 # broadcast at thinning	Ch

The crop was the locally recommended variety of sorghum for each centre. These were all of the Kaura or Fara-Fara races.

The full experimental description is given in Appendix 19.

Table 29: Granular herbicides, 1968

Grain yield, lb/acre

Treatment	-	F	Means
-	555 b	804 b	680 b
N	1166 a	1146 a	1156 a
Me	755 b	844 a b	800 b
Ch	676 b	898 a b	787 b
Atg	755 b	891 a b	823 b
S.E. diff.	±119.0		±84.2
Mean	781 b	917 a	
S.E. diff.	± 53.4		

The results may be summarised as follows. All striga control treatments produced yield increases and had negative interactions with the fertiliser treatment. The F fertiliser application produced yield increases except in the presence of the 'high N' striga control treatment. The average increase per cwt. from the latter was 155 lb. grain per acre as compared with the average increase of 136 lb. grain per acre from the F treatment. This comparison was not strictly valid because the significant F effect was averaged over the herbicide treatments. In the absence of herbicides

the F treatment produced an increase of 249 lb. grain as compared with 204 lb. grain per cwt. of compound fertiliser produced by the N treatment.

Table 30: Granular herbicides, 1968

Striga yield lb/acre (Mean of 5 experiments)

As air dry matter at harvest.

Treatment	-	F	Means
-	192	162	177 a
N	118	79	98 a b
Me	98	87	93 b
Ch	180	162	171 a b
Atg	126	155	140 a b
S.E. diff.		±41.6	±29.4
Mean	143	129	
		±18.6	

Meditonerb acetate significantly reduced striga dry matter at harvest and the average reduction caused by the 'high N' treatment was nearly as large. None of the materials completely suppressed striga or even reduced striga seed production to the extent that a long term decrease in striga population could be expected.

Striga yields were not reported for three out of eight experiments.

Table 31: Granular herbicides, 1968

Sorghum total dry matter as 1000 lb. per acre

Treatment	-	F	Means
-	5.74	7.21	6.48 b
N	12.71	12.96	12.83 a
Me	6.83	8.74	7.79 b
Ch	5.92	8.68	7.30 b
Atg	7.70	8.73	8.22 b
S.E. diff.	±1.21		±.858
	7.78 b	9.26 a	
	± .542		

All striga control treatments increased sorghum dry matter production. The N treatment gave an increase per cwt. of compound fertiliser of 2,120 lb. which was considerably greater than the 1,480 per cwt. obtained with 1 cwt. placed in the seedbed. Except in the presence of the atrazine treatment, the increase in dry matter production of the sorghum was accompanied by a decrease in the dry matter production of the striga. This appears to be good supporting evidence

that the inverse correlation of these two parameters is mainly due to the reduction in light energy reaching the striga.

(d) Estimated profitability of granular striga control materials

One hundredweight of compound fertiliser placed in the seedbed gave a yield increase of 136 lb. of grain per acre.

Three hundredweight of compound fertiliser broadcast at thinning time gave an increase of 476 lb., equivalent to 159 lb. of grain per cwt. The current price for this type of fertiliser (December 1969) is £1. 17. 0d per cwt. It would therefore be profitable to use this fertiliser application whenever the price of grain exceeded 2.8 pence per lb. There was no increase in yield when the seedbed fertiliser application was present in addition to the striga control fertiliser application.

The effects of seedbed fertiliser and herbicide were additive however. Assuming the 'break even' price of 2.8 pence a pound for grain, the limiting costs of the herbicides would be as follows:-

Meditonerb acetate	9/4 per lb a.i.	(No Nigerian sales)
Chlorthiamid	25/- per lb a.i.	(1969 price 51/-)
Atrazine	11/1 per lb a.i.	(1969 price 50/-)

The responses to fertiliser quoted here should be compared with the figures from the 2,4-D microgranular series on p. 167. In a lower yielding series, one hundredweight of compound fertiliser placed in the seedbed gave a yield increase of 219 lb. of grain per acre, while three hundredweight broadcast at thinning time gave only 290 lb. The differences in responses are probably due to the environments of the two series. The granules experiments were all in cotton growing areas, while the microgranular trials were in the drier groundnut areas.

(e) Conclusions

9. The 1967-8 results with single applications of granular herbicides showed that the main effect of these materials was to stimulate yield. None of them prevented striga from setting seed. A heavy application of fertiliser had similar effects and was marginally profitable in one series of trials.

The herbicide application rates used were decided by reference to the pot test results. Future work will examine the effects of different application rates of herbicides, combined with heavy fertiliser rates, but it does not appear that any of the materials tested in States experiments so far are active and selective enough to give effective control of striga.

The search for selective soil acting herbicides must therefore continue.

CHAPTER 9

CONTACT APPLICATIONS OF HERBICIDES

(a) Samaru, 1968

On the basis of the 1967 screening test results, a small scale experiment to assess the volume of herbicide required to give complete control of striga was performed at Samaru in 1968.

15 herbicides + 1 untreated control were used in a simple lattice design. A very striga susceptible "FF x CBK" sorghum strain was sown. The experimental routine adopted prescribed the weekly spot spraying of all green and turgid emerged striga plants. The number of plants and the volume of herbicides used were recorded. For full details of the experimental description see Appendix 16.

i. Results

The results at harvest are summarised in Table 18. The treatments are ranked in order of the final striga control.

The striga counts at harvest were rather higher than at the last treatment count on 19/11. This was mainly because the harvest count included dead as well as living strigas. Ametryne plots had significantly

fewer striga plants than the 'Untreated' plots. The total amount of herbicide used and the total volume applied were less than for a single soil application. No striga plants flowered or set seed during the experiment except on the 'Untreated' control.

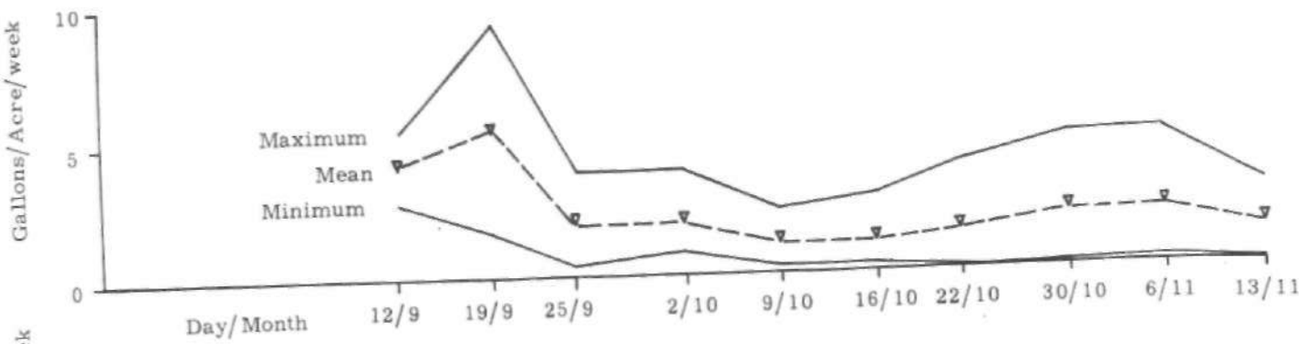
ii. Amount and frequency of herbicide applications

Striga emergence was first observed at 17.7.1968 and the first flower on 21.8.1968. Herbicide applications should have been started at this date but were delayed by sprayer defects until 12.9.1968. Ten applications at approximately weekly intervals were then made until 13.11.1968. The experiment was harvested on 5.12.1968.

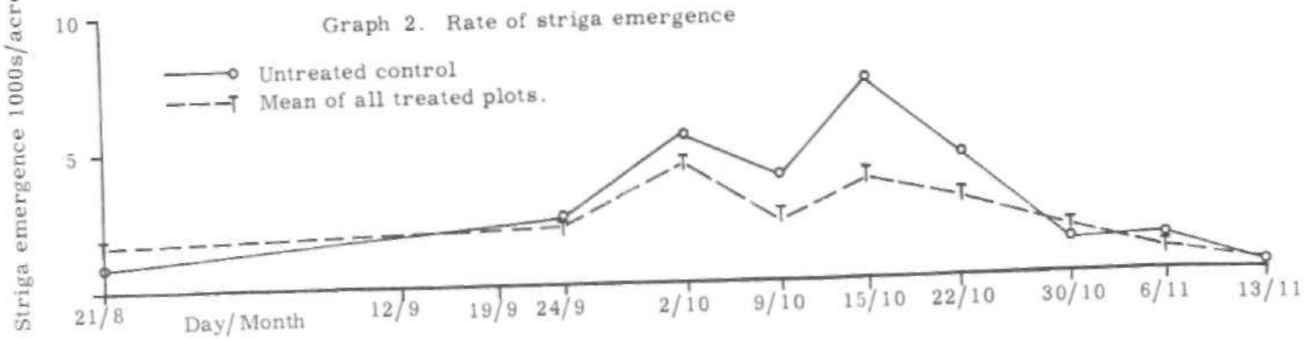
Details of the periodical and cumulative applications of herbicide are given in Tables 1 and 2 in Appendix 7. The limited replication of the experiment and the inherent variability introduced by the presence of striga produced relatively large standard errors. Table 1 is partly summarised in Graph 1, which shows the maximum mean and minimum herbicide applications at each application date. After the first two applications in which about five gallons/acre were used, the mean application rate dropped to between two and

Contact spray experiment, 1968

Graph 1. Rate of herbicide application



Graph 2. Rate of striga emergence



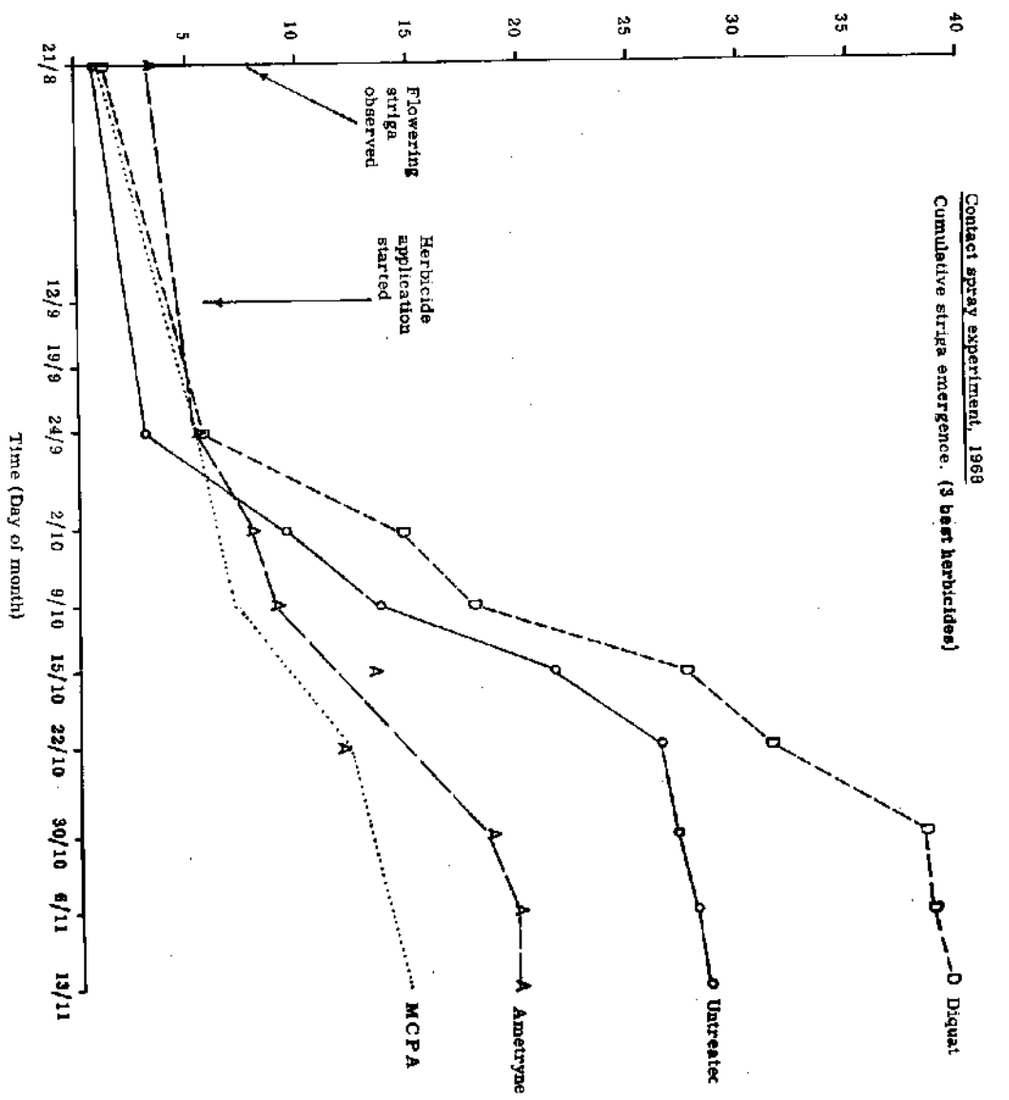
and one gallons/acre/week. It is of interest that from 9.10.1968 onwards the minimum rate dropped to negligible values indicating that striga emergence was virtually nil on these treatments at this time.

iii. *Striga emergence during the experiment*

New striga emergences in each plot were recorded at the time of herbicide application. Details of periodic and cumulative striga emergences are given in Tables 3 and 4 in Appendix 7. Graph 2 shows the rate of striga emergence per week for the mean of all treated plots compared with the untreated control. It can be clearly seen that most of the striga emergence occurred during October and that at the peak emergence on 15.10.1969 the mean effect of the herbicides was to reduce emergence to 48% of that of the untreated plots. 84% of the cumulative striga emergence occurred between 24/9 and 30/10 on the untreated plots with a lower proportion on the treated plots.

Herbicide application did not invariably result in lower total striga emergence. In Graph 3 the cumulative striga emergence for the three most successful herbicides in this experiment (which also represent the three main types of herbicide in the trial) are

Graph 3. Striga emergence 1000s/acre



plotted with the 'untreated' control included for comparison.

It can be seen that emergence was rapid from 24/9 until 22/10 on the 'untreated' control but thereafter proceeded at a very low rate. Emergence on the diquat treatment was slightly faster over the same period but continued until 30/10. As a result the total emergence was considerably higher than in the control treatment. This behaviour was to be expected with a purely contact herbicide, which was not translocated and behaved essentially as the herbicidal equivalent of handpulling.

Emergence in the ametryne and MCPA treatments was at a lower rate throughout the period of maximum emergence and continued for rather longer. Both these materials were certainly translocated and ametryne is also strongly soil acting as well. Too much importance should not be attributed to treatment differences in an experiment with only two replicates but it would seem possible that the longer period of striga emergence in the herbicide treatments was due to increased host vigour caused by earlier striga control.

iv. Relation of striga emergence to grain yield

(See Appendix 7, Table 5)

In this experiment, the yield of grain was significantly correlated (positively) with the volume of herbicide applied at 23.10.1968. (The best correlation was the inverse relationship with the reciprocal transformation.) There were good positive correlations of grain yield with volume of herbicide applied at 2.10.1968 and 30.10.1968. The amount of herbicide applied at the end of September and also at the end of October, would therefore seem to be particularly important for improving grain yields. The exact mechanism of the relationship is not clear but it would appear that emergence of striga at these periods reflected the vigour of the crop rather than the original infestation.

The grain yield was positively correlated with striga emergence at 23.10.1968 and 30.10.1968. (The inverse relationship with the reciprocal transformation was significant at $P = 0.05$ on both dates but the best correlation on 30.10.1968 was with the cube root transformation.) These observations support the hypothesis that striga emergence during the later

Table 32: AM14(68) - Striga Control Sprays, Results at harvest

Treatment /dosage #		Striga count* 1000/ac.	Striga weight* lb/ac.	Grain weight lb/ac.	Total D.M. 1000 lb /acre	Total vol. herbicide gallon /acre	Total herbi-cide	Grain response /lb. herbicide
Ametryne	0.2	0.23 a	0.00	1028	7.40	19.1	0.252	1798
MCPA	0.2	1.11 a	2.06	666	8.34	13.4	0.176	517
Diquat	0.2	1.12 a	0.88	938	6.79	25.2	0.332	1093
Fenac	0.3	1.40 a	11.35	786	6.20	19.6	0.387	545
2,4,5-TPK	0.5	1.42 a	1.50	786	6.80	15.7	0.517	408
Monuron	0.3	1.89 a	6.28	877	7.91	23.0	0.454	665
Linuron	0.3	1.91 a	17.77	998	6.48	24.0	0.474	892
Atrazine	0.2	2.01 a	5.98	908	7.88	18.8	0.248	1343
2,4-D (Na)	0.2	2.24 a b	3.41	847	9.90	26.4	0.348	782
Amitrol-T	0.5	2.32 a b	0.00	756	5.15	28.0	0.922	196
CMPP	0.4	2.82 a b	9.74	817	9.01	16.3	0.429	564
Paraquat	0.1	2.94 a b	1.73	696	6.57	21.2	0.140	864
2,4,5-T	0.2	3.84 a b	45.57	877	6.99	20.4	0.269	1123
Cypromid	0.4	4.03 a b	19.78	968	8.08	29.3	0.772	509

Table 32 (contd.)

Treatment		Striga count 1000/ac.	Striga weight lb/ac.	Grain weight lb/ac.	Total D.M. 1000 lb /acre	Total vol. herbicide gallon /acre	Total herbi-cide	Grain response /lb. herbicide
MCPB	0.2	4.83 a b	36.00	756	6.77	27.5	0.362	500
Untreated	-	10.67 b	58.28	575	6.13	-		
		±1.852	±20.389	±266.9	±2.587	±9.57		

* Includes all living or dead striga plants present at harvest

stages of the crop was dependent on host crop vigour and showed the effects of herbicidal applications earlier in the season.

v. Profitability of the spot spraying method

Considerable responses in grain yield were observed in this experiment using a striga susceptible sorghum strain. 0.25 lb. ametryne costing 50/- per lb. increased yields by 453 lb. of grain. The 'break even' price of grain was therefore 0.33 pence per lb. The farmer's labour need not be charged against the control method because handpulling of striga has to be done in any case if spot spraying is not used. Depreciation or hire of a knapsack sprayer would have to be charged in addition to the cost of the herbicide. A precise estimate of this latter cost is outside the scope of the present enquiry but a comparison with the insecticidal spraying of cotton indicates that it would be unlikely to exceed 10/- per sprayed acre per year. The control method would still remain profitable.

vi. Conclusions

10. This experiment demonstrated that weekly spot spraying was a technically sound method of suppressing vegetative striga and completely preventing

striga flowering.

11. The grain responses from ametryne and other contact herbicide treatments would have been profitable under the conditions of this experiment.

(b) Tolerance of sorghum intercrops

States experiments, 1968

In order to obtain some information about the practicability of foliar applications to striga growing in mixed crops, a series of five trials was laid down using a formalised mixed crop of sorghum, groundnuts and cowpeas.

The design of the experiment was a 2 x 4 factorial twice replicated.

The treatments were as follows:-

Striga control treatments	Symbol
70.6 lb fertiliser N + 47.0 lb fertiliser P, broadcast as 21-14-0 compound at thinning	NT
Monuron 0.5 # sprayed at first striga flower	MS
Atrazine 0.5 # sprayed at first striga flower	Ats.
Untreated	-
Fertiliser treatments	
23.5 lb fertiliser N + 15.7 lb fertiliser P placed as 21-14-0 compound before sowing	F
Nil	-

The herbicides were applied with a knapsack sprayer and directed at emerged striga. So far as possible the intercrops were not sprayed with herbicide.

Two rather non-selective herbicides which were active against striga were selected in order to maximise possible damage to intercrops from the spray application.

Plot size: Gross 6 x 9 yd ≈ $\frac{1}{89.6}$ acre

Net 5 x 8 yd ≈ $\frac{1}{121}$ acre

Each net plot contained 3 rows of sorghum interplanted with 1 row of groundnuts and 1 row of cowpeas.

For fuller details see the experimental proposal in Appendix 20.

Results

Table 35: Foliar application to mixed crops, 1968

Detailed Sorghum results

No. of experiments:

Treatment		5 Sorghum grain lb/ac.	2 Sorghum total dry matter 1000 lb/ac.	5 Striga total dry matter lb/ac.
-	-	620 b	8.8 b c	41.7
-	NT	1119 a	13.4 a	37.5
-	MS	927 a b	8.5 c	43.1
-	Ats	892 a b	9.2 b c	47.0
F	-	1099 a	12.4 a b	51.3
F	NT	1198 a	14.1 a	23.2
F	MS	853 a b	9.1 b c	59.3
F	Ats	1048 a b	13.1 a	30.7
		±138.7	±1.11	±15.04

Table 36: Mean treatment effects on yields of sorghum and intercrops

Treatment	No. of experiments 5 Sorghum grain lb/ac.	2 Sorghum total dry matter 1000 lb/ac.	2 Cowpea grain lb/ac.	2 Groundnut kernels lb/ac.
-	860 b	10.6 b	132.9	77.8
NT	1158 a	13.8 a	106.9	72.9
Ms	990 a b	8.8 c	99.6	96.5
Ats	970 a b	11.1 b	60.4	83.8
S.E. diff.	±98.1	±0.78	±27.51	±22.47
-	889 e	10.0 e	97.4	74.8
F	1049 d	12.2 d	102.5	90.7
S.E.diff.	±69.3	± .56	±19.39	±15.89

Atrazine and monuron gave small increases in grain yield while 3 cwt of compound fertiliser applied at thinning produced a large and significant increase in the absence of seedbed fertiliser. The overall effect of placed fertiliser was a significant increase.

In the two experiments for which the sorghum dry matter weights were measured, monuron significantly depressed yields and the 3 cwt of fertiliser gave a large and significant increase.

There were no significant differences in either cowpea or groundnut yields though both herbicides reduced the yield of cowpeas considerably and increased the yield of groundnuts slightly. The reduced yield of cowpeas on the NT treatment was almost certainly due to increased competition from the sorghum.

In future experiments, sorghum will have to be sown at an even lower stand in order to allow adequate light energy to reach the intercrops. This will also encourage more vigorous striga emergence.

In this series, atrazine lowered cowpea yields considerably and though this depression was judged not significant using Tukey's test, it would have been considered significant if the conventional T test had been used. Pending confirmation of this result, atrazine will not be used on non-experimental crop mixtures containing cowpeas but even this scale of loss may well be acceptable to farmers on badly striga infested land in exchange for a considerably improved yield of sorghum grain.

(c) Ametryne toxicity observation plots, Samaru 1967

When the first results of the 1967 contact activity screening trial indicated that ametryne was a promising

material for foliar application to striga, a number of observation plots of cowpeas, groundnuts and sweet potatoes were sprayed overall with ametryne at 0.2 #. It was too late in the season for meaningful yield differences to be observed but no herbicide toxicity symptoms were observed on the cowpeas or groundnuts. A slight and transient chlorosis was reported on one sweet potato plot but this could not certainly be attributed to the effect of the ametryne.

CHAPTER 10

DISCUSSION

(a) Stage I testing

The results obtained during Stage I testing are discussed in Chapters 6 and 7. In this section the screening methods which were used are compared and improvements are proposed for future use.

i. A comparison of screening methods

The arguments quoted in Chapter 3 (page 64) for using pot tests to detect selective activity have not all been justified. The variability between pots was not markedly smaller than in mini-log plots in the field. Difficulties were also experienced in carrying on pot tests during the dry season. In spite of these defects however, selective activity against striga parasitising sorghum was detected in many herbicides which were not previously reported to possess it.

In the absence of any other information, the optimum dosages of herbicides indicated by pot tests had to be used in field experiments in 1968. Their performance in the 1968 granules experiments showed that these dosages were of the correct order. The pot tests therefore successfully detected selectivity

and indicated the order of the dosages to be used in the first field tests of herbicides.

The field screening tests used in 1967 and 1968 were not very informative, mainly because of the difficulty of ensuring the presence of striga before treatment. In 1969 the adoption of the principle of not applying the herbicide until after emergence had proved the presence of striga, removed practically all of the difficulties of interpreting the results.

The immature striga which was handpulled during September and October in the 1968 granules experiment at Samaru (page 173) invariably re-emerged within one week. Exactly the same behaviour was observed when striga was 'burnt-off' by sprays of paraquat or diquat. In the 1969 screening test therefore, a delay of more than one week before re-emergence after contact spraying, unambiguously detected soil activity in the herbicide under test. This technique is therefore regarded as positive and reliable. It is as easy to perform as a pot test and is much easier to interpret. The main disadvantage is that about 20 g. of herbicide active ingredient are required for a single mini-log plot, as compared with the milligram quantities

required for a well replicated pot test. Pot tests may therefore still be occasionally required in future to screen new herbicides which are only available in gram quantities.

Conclusion

12. In any method of screening herbicides to detect activity against striga it is desirable that the presence of striga be confirmed by its emergence above ground before the herbicide is applied.

ii. The selection of constant dosages for initial screening tests

Activity which is potentially of practical use has been observed at three levels of application.

Contact active materials gave good control of emerged striga at 0.1-0.3 lb a.i./sprayed acre in 1968 and 1969. There is therefore no need to test new herbicides for contact activity outside this range.

Soil acting herbicides giving an increased yield of sorghum and partial control of striga were tested in the 1968 granules experiments at a dosage of 1 #.

Two well tolerated herbicides (meditonerb acetate and atrazine) were applied at 3 #. At this dosage at Samaru, atrazine gave good quantitative control of striga and almost perfect general weed control.

It is possible that farmers might use this type of application in future at high levels of anticipated yield in spite of the high cost of herbicide. The more sophisticated type of farming involved would permit the use of a lower selectivity ratio.

When the investigation started, it was hoped that a selectivity ratio of 3 to 1 would be safe for hand farmers to use. Observations (see Appendix 20) were made on the variations from the intended dosage which occurred when inexperienced labourers broadcast granular herbicides or made contact applications with a knapsack sprayer. They showed that a selectivity ratio of at least 5 to 1 would be required to reduce the chance of the herbicide damaging the sorghum to 5%.

The minilog plot covering much more than the potentially useful range of dosages could therefore be replaced in future tests by three constant dosage plots at 0.2 #, 1.0 # and 5.0 # respectively. The function of each dosage would be as follows.

At 0.2 # to test for contact activity and very high soil activity

At 1.0 # to test the selectivity ratio for the 0.2 # applications and to measure soil activity on grain and striga production.

At 5.0 # to test the selectivity ratio for the 1 # dosage and to observe whether complete striga and general weed control occur without damage to the sorghum.

The use of the 5 # dosage would also test the selectivity ratio of a possible 3 # dosage for use by sophisticated farmers at a value of 1.8 to 1. This is close to the minimum selectivity ratio required by skilled operators. (See Appendix 21)

Conclusion

13. In future, field screening tests the herbicides should be tested at three constant dosages instead of in minilog plots.

iii. Quantitative measurement of selectivity during the initial screening

The adoption of constant test dosages applied after the first striga emergence would make it possible to measure the effect of the herbicide on the sorghum quantitatively. Any herbicide which demonstrated soil activity (see page 200) could be re-applied as soon as any striga re-emerged. The emerged striga would be pulled out. In this way the number and frequency of the applications of a soil active dosage would be

decided mainly by the persistence of the herbicide. Under this herbicide regime, the interplot variation in striga infestation would have small effect on sorghum growth because herbicidal control would ensure that there would be few active strigas present except just before re-emergence.

The variation would still affect sorghum growth before herbicide application commenced and a method of estimating and adjusting for the variation would be required.

At harvest the yield of dry matter and grain (if any) would be compared with the yields from a control treatment receiving no herbicides from which all emerged striga would be pulled weekly.

The repeated application of non-selective herbicides would produce dead or damaged sorghum plants at harvest. A ranking analysis similar to that used for pot tests could then be used to measure treatment effects on sorghum vigour and maturity.

The interpretation of these results in the absence of emerged striga would be comparatively simple. A negative deviation from the control would indicate that the applied treatment was toxic to the sorghum. A positive deviation would indicate that the applied treatment was selectively soil active. The intensity of the activity would be assessed by comparing the deviation with the deviation produced by a herbicide of known activity in the same experiment.

Conclusion

14. Future field screening should be performed at herbicide dosages and frequencies needed to prevent striga emergence completely.

(b) Soil activity against striga

i. A standard soil application for Stage II testing

The herbicides which were Stage II tested in granular formulation in 1968 are discussed in Chapter 8. It is clear that, though there is scope for increasing their effect by alterations in dosage and timing of applications, none of these materials provides a practical answer to the problem of profitable striga control with a single application. The use of 69 lb.

of fertiliser N and 46 lb. of fertiliser P did give yield increases which were profitable in some areas and reduced striga almost as much as the best herbicide. This treatment will therefore be used as a field standard for future comparisons with herbicides in straight crop tall sorghum. There is no evidence that this application has genuine herbicidal effects or that it would reduce striga in widely spaced sorghum growing in mixed crop. The reduction in striga which occurred in the 1968 tolerance of sorghum intercrops trials was at a much higher sorghum stand than is usual in farmers' mixed crops.

Conclusion

15. An application of 69 lb. of fertiliser N and 46 lb. of fertiliser P per acre could be used as a standard for comparisons with soil applied herbicides in straight crop tall sorghum.

ii. The completion of the testing process in Stage II

Before the testing of the granular herbicides now in Stage II ceases, the dosages and frequencies of application of the most selective materials which completely suppress striga emergence will be determined. The cost of eradication by soil application will then be calculated.

iii. The prospect for profitable striga control

A considerable number of selective herbicides await Stage II testing in granular formulation Amongst these, nitralin, pyrazon and tri-allate all seem to be much more active against striga than the materials tested earlier. Tri-allate is an interesting example of a material which was more active in the field than was indicated by the pot tests. This is probably because it required incorporation when applied as a spray. These more active herbicides can give the same control of striga at lower dosages than the materials tested in 1968. The possibility of profitable herbicidal control will therefore be increased providing that the selectivity ratios are not markedly lower.

iv. Methods of application

The method of applying herbicide granules by hand broadcasting has proved satisfactory and may be expected to give good control from a single application when more active herbicides are used. Owing to the variations in the application rate which occur with this method (see Appendix 15), it is unlikely that complete control of emergence would ever be obtained

with a single application of herbicide granules. Multiple applications would almost certainly be necessary to produce the even herbicide cover which would be required.

v. The best time for herbicide application

The limited information so far available (Chapter 8, page 167) has confirmed the findings of Wilson-Jones (1952, 1953 and 1956) that a 2,4-D herbicide application shortly after sowing gave better grain yields and better striga control than a pre-sowing application. Later applications further increased the yield at Samaru (Chapter 8, page 164) or gave yields of the same order as the post-sowing applications in the States experiment. The later application markedly reduced the weight of striga at harvest at Samaru but apparently increased it in the States experiment. There are reasons for believing that this result was misleading (page 168).

The only evidence for the best time of application of residual herbicides was provided by the 1968 granules experiment at Samaru. The application at thinning time gave a slightly higher yield than the pre-sowing application (page 171) but this difference

was reversed if the ineffective herbicides fenuron and prometryne were excluded from the calculation. The yields were then 718 and 642 lb. of sorghum grain per acre at the pre-sowing and thinning time applications respectively. Three out of the five effective herbicides produced small increases and the remainder small decreases when applied pre-sowing. It appears that there was no marked advantage for either time of application.

Bearing in mind the considerable proportional yield increases obtained by controlling striga only after emergence (page 191), with foliar application it seems probable that similar increases could be obtained with late applications of soil active herbicides. These would also be active for a greater proportion of the period of striga emergence than applications made pre-sowing or at thinning.

vi. The value of general weed control

Materials like atrazine which appear only to be active against striga at dosages high enough to give general weed control could be applied pre-sowing to take advantage of the early general weed control. Very few Nigerian hand farmers would be prepared to

spend the £6 per acre which this would cost at current prices, even though the combined effects of the application might be profitable.

In contrast, tri-allate appears to be toxic to sorghum when applied in the seedbed at normal general weed control dosages (see page 256) but is selectively active against striga at low dosages (see page 144) when applied after striga emergence.

This material and others like it will probably be applied when the striga infestation first becomes evident. This will either be when striga first emerges or when clear foliar symptoms develop. (See Appendix 1, b). It is anticipated that Nigerian farmers would be prepared to pay the rather smaller cost of applying a low dosage of an active herbicide to rescue their crop.

Conclusion

16. Soil active herbicides should be tested in Stage II by applying them in granular formulation at the time of first striga emergence.

(c) Selective contact herbicides for the control of emerged striga in mixed crops

i. Ametryne

At 0.2 # ametryne appears to be tolerated by

groundnuts and cowpeas without visible damage. It has a low mammalian toxicity, low volatility and generally good storage properties as a dry powder formulation. The period of persistence in the soil at the dosage applied seems to be of the order of two weeks at Samaru, judging by the periodicity of striga emergence at Samaru in 1968. (See Table 3, Appendix 7) There is therefore little or no danger of residual toxicity from this material. The characteristics of this herbicide are so outstanding when it is used as a foliar spray that it was nominated for Stage III testing in 1969, even though its effects on the yield of all the common mixed crops have not yet been fully tested.

ii. Other contact active herbicides

Several of the other materials which were applied in the 1968 sprays experiment controlled striga well but are not suitable for application by hand farmers on mixed crops.

The 2,4-D group herbicides are too toxic to mammals and some common mixed crops. Seeds and fertilisers stored in farmers' huts are easily contaminated by vapour and leakage from containers of these herbicides.

Diquat and paraquat not only damage other crops but are hazardous if absorbed through the skin or inhaled. They would be suitable for estate use in pure stand.

Linuron, monuron and atrazine are all materials which are contact active and may be of use in certain crop mixtures where ametryne causes damage. Their selectivity and activity might be improved by additives. As an example, an atrazine-oil emulsion has been received for test at Samaru.

Conclusion

17. Enough herbicides have been shown to possess contact activity against striga to suggest that a suitable one should be available for use with any of the main crop mixtures grown in the savanna area.

(e) Evidence for stimulation of striga emergence by a herbicide formulation

A subsidiary objective of this project was to identify herbicides which stimulated striga emergence.

i. Pot test observations

A commercial formulation containing noruron (N'-(hexahydro-4,7-methanoidan-5-yl)-NN-dimethylurea) 15% a.i. and DSMA (disodium methanearsonate) 45% was tested

in pots for striga control and was classed as moderately selective. It was noticed that an unusually large number of striga seedlings emerged in this treatment, most of which died shortly after emergence.

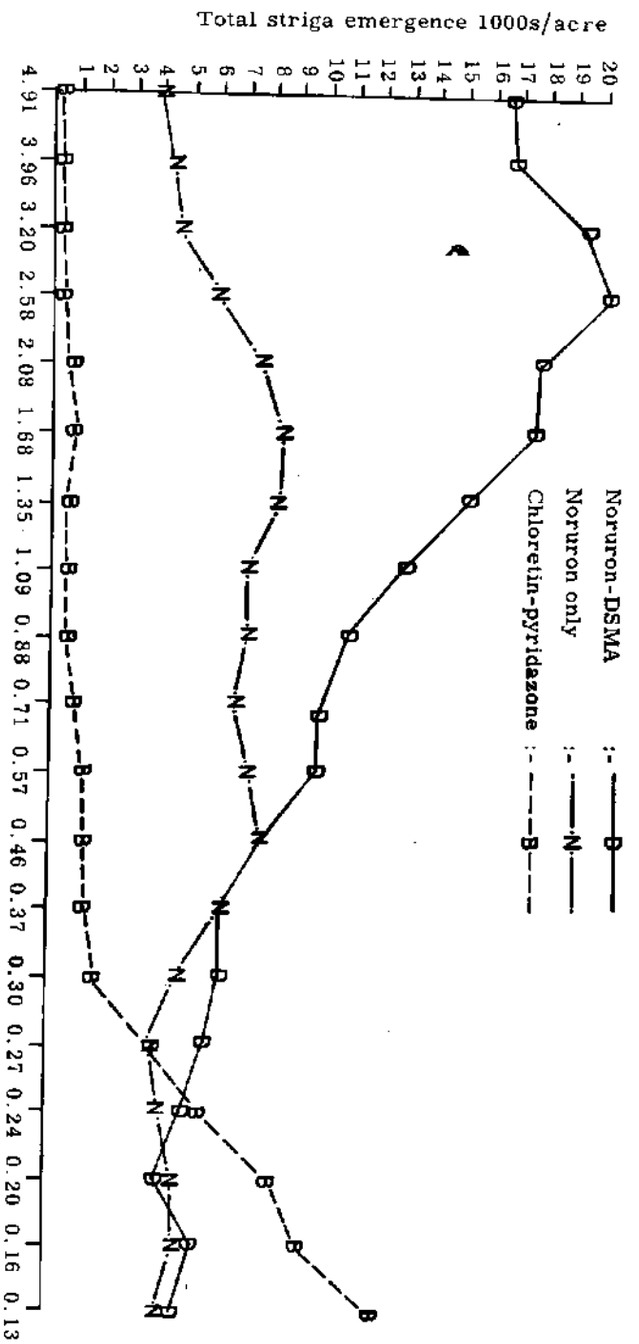
ii. Minilog field observations

The formulation was tested in the field in the combined minilog screening test 1969 (see Appendix section 3). In the field, the formulation showed mediocre contact and soil activity but an unusual pattern of striga emergence was observed. As can be seen in Graph 4, both noruron-DSMA and noruron alone produced the highest total emergence between dosages of 4.0 to 0.3 #.

In contrast, a persistent soil active material like chloretin-pyridazone in a plot adjacent to noruron-DSMA suppressed emergence at these dosages and the emergence only increased below a dosage of 0.3 #.

iii. Evidence from the 1969 contact applications experiment

The formulation was also included in the 1969 contact sprays experiment. The full results of this experiment were available too late for inclusion in this thesis but some of the results obtained up to 30.10.1969 appear to support the proposition that the



Graph 4. Total striga emergence on miniog screening test 1969

noruron-DSMA formulation at least produced a real increase in striga emergence.

Table 37: 1969 contact sprays experiment

Estimated number of 'green and turgid' striga stems (1000s/acre) treated each week by spot spraying at a dosage of 0.1 # .

Treatment name	10.9.69	2.10.69	30.10.69	Weekly mean
Untreated	14.9	18.2	5.3	13.2
Hand pulled	20.9	10.1	16.2	14.8
Noruron	15.5	16.8	2.4	12.9
Noruron-DSMA	20.0	70.2	24.7	46.5
Ametryne	24.7	4.8	1.0	9.1
S.E. diff.	±15.21	±19.40	±8.60	±12.21

Herbicide applications were started on 10.9.1969, at which date noruron-DSMA had a total emergence of the same order as the other treatments in the table. Three weeks later (2.10.1969) the number of striga plants was three and a half times the original emergence, while the striga numbers on the other treatments had changed little or had dropped considerably. Even by 30.10.1969, when the number of green and turgid striga

plants on the noruron-DSMA treatment was still over four times as high, and was even higher than the population on the hand pulled plots, which was still increasing at this date.

Noruron alone did not appear to stimulate emergence and was mildly active against the striga.

The available evidence therefore suggests that DSMA is the component which might stimulate emergence, though noruron may do so at dosages between 4.0 and 0.3 #.

The stimulating range of dosage indicated by the minilog plots could easily overlap the total dosage applied to small areas of emerged striga in the sprays experiment but the increase in emergence was so rapid that it is more likely that the method of application increased the stimulating effect.

The contact application would favour the activity of the DSMA which is rapidly inactivated by contact with soil (Palm et al, 1968). It seems likely therefore, that any stimulation of emergence by DSMA occurs either through translocation in emerged striga plants or through translocation in the host.

Further work is required to confirm that a real

stimulation is produced by the noruron-DSMA formulation. A considerable advance in control methods should then be possible. If the stimulation only occurs in the presence of a susceptible host plant, the efficiency of a contact active herbicide could be increased by combining it with the noruron-DSMA formulation so that a larger number of striga would be exposed to the contact spray during the cropping season.

Stimulation which occurred in the absence of a susceptible host would permit the rapid eradication of striga by inducing all the viable seeds to germinate abortively.

CHAPTER 11

SUMMARY AND CONCLUSIONS

The economic and social importance of striga infestation was described in Chapter 1, showing that the discovery of a selective soil acting herbicide to control it would be a fundamental advance.

The literature was reviewed in Chapters 2 and 3. Many publications about the physiology of this parasite were cited. Suggested methods of controlling it with catch crops or trap crops were referred to but only the phenoxy-acetic acid group of herbicides have been thoroughly tested for chemical control. These herbicides were shown to be unsuitable for use by unsophisticated farmers.

The research objectives were listed in Chapter 3 as follows:

Objective 1

To identify soil acting herbicides for pre-emergent control of striga in mixed crops.

Objective 2

To search for selective contact herbicides for the control of emerged striga in mixed crops.

Objective 3

To develop simple methods of application.

Objective 4

To identify herbicides which promote striga emergence.

Three stages were defined for developing a new herbicide practice:

Stage I

The detection of desirable activity in a herbicide.

Stage II

Evaluation in the environment.

Stage III

The development of a practicable recommendation.

Observations in Stage I, Objectives 1 and 2

The selectivity of 60 herbicides was determined in pot tests and others were partially tested. Uncontrollable variability made it necessary to develop complicated methods of assessment. Selective activity against striga was observed in 11 chemical groups of herbicides.

Screening tests using the minilog sprayer were also performed in the field. The large well replicated

noruron-DSMA formulation at least produced a real increase in striga emergence.

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stimulation is produced by the noruron-DSMA formulation. A considerable advance in control methods should then be possible. If the stimulation only occurs in the presence of a susceptible host plant, the efficiency of a contact active herbicide could be increased by combining it with the noruron-DSMA formulation so that a larger number of striga would be exposed to the contact spray during the cropping season.

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The selectivity of 60 herbicides was determined in pot tests and others were partially tested. Uncontrollable variability made it necessary to develop complicated methods of assessment. Selective activity against striga was observed in 11 chemical groups of herbicides.

Screening tests using the minilog sprayer were also performed in the field. The large well replicated

tests in 1967 and 1968 were not very informative because of variability in striga emergence. This difficulty was overcome in 1969 by applying the herbicide after the presence of striga had been proved by emergence.

Results were reported for 20 herbicides screened in 1967, 30 screened in 1968, and 42 screened in 1969.

The results from the field tests generally confirmed the indications of the pot tests.

A preliminary test in 1967 showed that 12 out of 25 herbicides killed striga by contact at dosages of 0.3 # or less. Several of the active herbicides were reported to be tolerated by crops commonly grown in mixture with sorghum.

Abstract of conclusions in Stage I

1. The pot tests were a satisfactory primary screen for detecting selective activity against striga.

2. The use of a parameter based on objective ranks gave a good measure of herbicidal activity.

3. Future development of the pot test method should measure the dosage of herbicide completely controlling striga emergence.

4. Striga control by repeated spot spraying

was potentially possible in crop mixtures.

5. Selective activity against Striga hermontheca occurs in many chemical groups of herbicides.

Observations in Stage III, Objective 1

At Samaru, 92 and 138 lb. of fertiliser N applied to tall sole crop sorghum at thinning time decreased striga and gave relatively large increases in grain yield per unit N as compared with 40 lb. fertiliser N in 1968. The same high rates of fertiliser N per acre failed to decrease striga in dwarf sole crop sorghum in 1969.

69 lb. of fertiliser N applied to tall sole crop sorghum at thinning time in two series of experiments in the States gave marginally profitable grain yield increases and reduced striga.

At Samaru and in the States in 1967 and 1968, granular formulations containing 2,4-D at 1 # reduced striga and gave some yield increases. There were indications that 2,4-D applied at sowing and thinning time damaged sorghum more than applications after striga emergence.

Other soil acting herbicides applied in granular

formulation in 1968 increased sorghum yields and reduced the above ground growth of striga.

None of the yield increases were profitable. No testing of granular formulations was done in mixed crops.

This type of control is potentially profitable when more active herbicides are discovered.

Abstract of conclusions in Stage II, Objective 1

6. The evidence supports the view that the reduction of striga by high fertiliser N applications is mainly due to the interception of light by the crops.

7. Soil applied striga control treatments of fertiliser or 2,4-D granules gave increases in yield of grain but no effective reduction of striga. "Pre-sowing" was not the best time of application of 2,4-D.

8. At Samaru, residues of granular striga control herbicides were not harmful to following crops.

9. Single applications of soil active granular herbicides increased sorghum grain yields but did not prevent striga emergence.

Observations in Stage II, Objective 2

In straight crop sorghum, the herbicide ametryne

was outstandingly active against striga in 1968. 10 weekly spot sprayed applications totalling 0.252 # reduced striga emergence from 28.3 to 19.4 thousand per acre and killed all emerged striga.

A profitable yield increase of 453 lb. of grain per acre was obtained.

The herbicides monuron, linuron, and atrazine were also active and may be useful in crop mixtures containing crops which are damaged by ametryne.

Contact applications of monuron and atrazine at 0.5 # did not significantly lower yields of cowpeas or groundnuts in two States experiments in 1968.

No toxicity symptoms were observed from a late season contact application of ametryne at 0.2 # on cowpeas, groundnuts and sweet potatoes in 1967.

Abstract of conclusions in Stage II, Objective 2

10. Weekly contact herbicide applications were a technically sound method of striga control.

11. Profitable grain responses were obtained from ametryne and other contact herbicide treatments.

Objective 3

The manual application of granules used in

Stage II is suitable for use by hand farmers.

The spot spraying technique used in Stage II is technically suitable for use by hand farmers.

No other work was necessary for this objective.

Observations in Stage I, Objective 4

A noruron-DSMA formulation produced abnormally high numbers of emerged striga in pot tests. In minilog screening plots the emergence was greatest at dosages between 4.0 and 0.3 #.

In 1969 noruron-DSMA spot-sprayed produced 46.5 thousand striga emergence per acre as compared with an 'untreated' value of 13.2 thousand.

The available evidence indicates that the DSMA component of the formulation is most active in promoting emergences.

Abstract of conclusions in the final discussion

12. In any primary screening test it is desirable that the presence of striga be confirmed by emergence before a herbicide is applied.

13. In future field screening tests the herbicides should be tested at three constant dosages instead of in minilog plots.

14. Future field screening should be performed at herbicide dosages and frequencies needed to prevent striga emergence completely.

15. An application of 69 lb. of fertiliser N and 46 lb. of fertiliser P per acre should be used as a standard for comparisons with soil applied herbicides in straight crop tall sorghum.

16. Soil active herbicides should be tested in Stage II by applying them in granular formulation at the time of first striga emergence.

17. Striga control by contact herbicides should be possible in any common savanna crop mixture.

APPENDIX 1

Striga hermontheca in Northern Nigeria.

Botanical Observations on Striga hermontheca in Northern Nigeria.

a. The botanical identification of Striga sp. growing parasitically in sorghum fields at Samaru

i. Collection of specimens

Specimens were collected during September and October in 1966, 1967 and 1968.

The overwhelming majority of the plants appeared to be Striga hermontheca but because of the extreme variability of this species, not all specimens agreed completely with the flora descriptions.

Two other parasitic members of the family Scrophulariaceae were found in most sorghum fields. These were the white flowered Striga bilabiata sub species rowlandii and the mauve flowered Buchnera hispida. Buch-Ham. ex D. Dan Prod. Fl. Nepal 1.91 (1925) (engl) Hepper in Kew Bull. 14:411 (1960).

ii. Identification of Striga hermontheca, S. bilabiata and Buchnera hispida using the Flora of West Tropical Africa.

1. The flowers were not spurred.

2. The lower leaves were opposite

3. There were four stamens. This was often difficult to see but could be confirmed because none of the two stamened tribes agreed with the rest of the description

4. The leaves were not radical

5. The calyx lobes were equal

6. The stamens were inserted in the corolla tube

7. The leaves were entire

8. The anthers were 1-celled. The plants dried dark and were parasitic

9. The calyx teeth were not woolly inside
   The sequence identified Striga sp., Rhamphicarpa sp., Buchnera sp. or Cycnium sp.

10. The long corolla tube was curved in the middle and the lobes were unequal
    This sequence identified Striga sp.

S. Hermontheca

1. The calyx was 5 ribbed

2. The indumentum of the stems was erect and scabrid.

3. The corolla-tube was glabrous in most cases though some slightly pubescent specimens were

seen. At Samaru the flowers were usually opposite or sub-opposite. The Flora states that these are alternate. The stems were square but not sharply angular. The leaf-bases were not decurrent.

4. The bracts were lanceolate-elliptic usually with acuminate tips. The shape of the bract appears to be a very important distinguishing feature of this species. The bracts were ciliate on the margin. According to the Flora the bracts may also be ciliate on the outside of the midrib but this was not observed. The length of the bract varied from about 5 mm. to 15 mm. at Samaru and was not a good recognition feature. The leaves were linear, scabrid and very variable in length.

The tips were usually obtuse.

Very considerable variations in the compactness of the inflorescence were observed at Samaru. Plants were seen to flower when only 5 cm. high while some vigorous specimens were over 40 cm. high before the first flower opened. The plant dried bluish black. There are several

local specimens in the Samaru herbarium.
The flower colour varied from bright pink to a more bluish tint in older or moribund plants. It is doubtful whether there are strains with characteristic differences in flower colour.

S. bilabiata, subsp. rowlandii.

1. The calyx was 5-ribbed
2. The indumentum of the stem was erect and the stems were scabrid.
3. The corolla tube was tomentose. (This eliminated S. aspera)
4. The bracts were linear lanceolate, not acuminate and not imbricate.
5. The stems were square. The Flora describes it as being 'sharply angular' but only one out of three specimens had this characteristic. The leaf bases were decurrent. This was a good distinguishing feature of the species.
6. The leaves were linear with acute tips. They were usually less than the 5.5cm. maximum length given by the Flora. The plant dried greenish black. It has previously been reported from the area but there are no herbarium specimens.

The flower colour of this species can be mauve, pink or white. Only white flowered speciemns were observed at Samaru.

iii. Identification of Buchnera hispida using the Flora of West Tropical Africa

10. The corolla tube was straight

11. The fruits were straight and ellipsoid. The calyx was tubular

12. The corolla was small and always about 5 mm. long with subequal lobes. The fruits were dry and dehiscent.

This sequence identified Buchnera sp.

Buchnera hispida

1. The spikes were elongate

2. The leaves were linear-lanceolate

3. The plant was hispid. The calyx was densely hispid. The Flora states that the corolla tube is sparsely villous outside but at Samaru it was usually glabrous

4. The leaves were coarsely dentate

5. The flowers were mauve and the plant dried black.

This sequence confirmed the identification of Buchnera hispida. There are several local specimens

in the Samaru herbarium.

lv. Other Striga spp. which have been collected in the Samaru-Zaria area

S. brachycalyx. It is recorded in the Flora and there is a local specimen in the Samaru herbarium.

S. macrantha. There is a local herbarium specimen but the species is not recorded from the area in the Flora.

S. aspera. It is recorded in the Flora but there is no local specimen.

S. passargei. It is recorded in the Flora but there is no local specimen.

None of these species was collected during the current investigations.

v. Other host plants.

Striga hermontheca and Buchnera hispida were also observed growing parasitically on grasses in fallow land. The S. hermontheca plants were usually much reduced in size and often less than 10 cm. high at flowering. B. hispida usually grew to its normal size on fallow land. So far it has not been possible to distinguish which grasses were the susceptible hosts.

S. senegalensis is now regarded as identical

with S. hermonthca and no sub-species of this name is recognised by the 1963 edition of the Flora of West Tropical Africa.

b. A Note on the foliar symptoms caused by striga infestation of sorghum and maize.

These symptoms were described to the writer by Curtis (1966). A text with coloured photographs of the symptoms was prepared for publication by him at this time, but does not appear to have been published yet. The text is not available at Samaru at the moment and the following description is based on the writer's own observations.

Stage I

Pale green 'blotches' appear on the older leaf laminae. They usually appear at about two thirds of the length toward the tips. Curtis said that they were usually close to the mid-rib when they first started to develop but this has not been observed on the susceptible varieties B57 and A189. In these, the blotches are fairly evenly spaced over the whole surface of the leaf. Though the earliest stages of development are not easy to spot in the field they are very characteristic and difficult to confuse with any other foliar

symptoms once they have become familiar to an observer. The blotches are not sharp edged and are usually about three times as long as they are broad. Unlike most deficiency symptoms the whole leaf does not change colour nor are the veins made more prominent by developing different colour from the rest of the leaf surface. This stage of the symptoms can appear as early as twenty days after sowing, on the susceptible varieties growing in pots in a greenhouse. On variety A189 they were observed three weeks before striga emergence but on variety B57 they developed as much as eight weeks before emergence of striga. On resistant or tolerant local Nigerian varieties in the field the symptoms may not appear until after striga emergence but almost always develop within the week before or after the emergence.

Stage II

The tip of an affected leaf becomes necrotic (Curtis called this 'tip-burn') shortly after striga emergence and this is followed by the rapid development of necrotic strips down the edges of the leaf starting from near the tip but often not initially connected to the area of the tip burn. In the field, strips of

necrotic material may develop next to the midrib. The blotching on the remainder of the leaf surface becomes more intense until eventually the whole leaf appears to have changed colour. Usually three or four leaves will show some symptoms in a badly affected plant.

Stage III

Eventually the whole plant becomes covered with chlorotic blotches and necrotic strips. The speed at which the final stage of the symptoms develops depends on the severity of the striga attack and the tolerance of the sorghum variety. Though growth may be severely stunted by striga parasitism without emergence the most severe symptoms only develop if the striga emerges and is allowed to grow undisturbed. A badly attacked sorghum plant is unable to produce an inflorescence or seed.

APPENDIX 2

List of plants whose root exudates cause the germination of Striga hermonthecа seed

This list is based on a list in USDA (1957). A very large number of Gramineae are quoted in the table but only those commonly occurring in northern Nigeria are included here.

Gramineae	Authority		Host status
Cenchrus biflorus Roxb	Wilson-Jones	(1957)	H
Cynodon dactylon (Linn) Pers	Andrews	(1945)	H
Digitaria exilis (Kippiest) Stapt	Porteres	(1948)	H
Echinochloa colonum (Linn) Link	Wilson-Jones	(1957)	H
Eleusine coracana (Linn) Gaertn.	Wilson-Jones	(1957)	H
Oryza glaberrima Steud.	Porteres	(1948)	H
Oryza sativa Linn.	Andrews	(1945)	H
Paspalum orbiculare Forst.	Andrews	(1945)	H
Pennisetum typhoideum.	Andrews	(1945)	H
Saccharum officinarum Linn.	Wilson-Jones	(1957)	H

Sorghum arundinaceum (Desv) Stapt.	Wilson-Jones	(1957)	H
S. sudanense	Wilson-Jones	(1957)	H
S. vulgare	Andrews	(1945)	H
Zea mays	Andrews	(1945)	H
<u>Leguminosae</u>			
Arachis hypogaea L.	Andrews	(1945)	H
Cajanus cajan Millsp.	Andrews	(1945)	H
Cassia ashrek. Forsk	Andrews	(1945)	I
Cicer arietinum L.	Andrews	(1945)	I
Crotalaria juncea L.	Andrews	(1945)	I
Dolichos lab-lab L.	Andrews	(1945)	H
Glycine max (L.) Merr.	Andrews	(1945)	S
Lupinus termi Forsk.	Andrews	(1945)	I
Medicago sativa Linn.	Andrews	(1945)	I
Phaseolus vulgaris Linn.	Andrews	(1945)	I
Pisum sativum Linn.	Andrews	(1945)	I
Vicia faba Linn.	Andrews	(1945)	I
Vigna unguiculata Walp.	Andrews	(1945)	S
<u>Other families</u>			
Cucumis melis L.	Andrews	(1945)	I
Gossypium barbadense Linn.	Andrews	(1945)	I
Gossypium hirsutum Linn.	Dogget	(1954a)	I

Helianthus annuus Linn.	Andrews	(1945)	I
Linum usitatissimum	Sunderland	(1960)	I

Host Status

'H' - (Host) indicates that Striga hermontheca is reported to parasitise the species and to develop fertile seed.

'S' - (Susceptible) indicates that Striga hermontheca is known to parasitise the species and reduce its vegetative vigour but has not been observed to develop aerial stems or fertile seed.

'I' - (Immune) indicates that though Striga hermontheca is stimulated to germinate it is unable to parasitise the species.

APPENDIX 3

Striga Pot Tests. Experimental Instructions

Object

To measure the toxicity of herbicides to sorghum and striga when the herbicides are applied post-emergent to the sorghum and pre-emergent to the striga.

Design

Triple square lattice of 16 treatments and 48 pots.

Procedure

Weigh 11 Kg. of soil into 48 polythene bags 18" x 12" using transparent polythene bags with drainage holes. Add 2 l. of water over night. Sow 5 seeds of sorghum variety A189 on to the soil surface. Press the seed firmly into the soil and just cover with dry soil. Sub-irrigate immediately. One week after sorghum emergence thin the sorghum to one plant per pot. Then sow a 'pinch' (enough to cover a penny) of the oldest available provenance of striga seed round the base of the sorghum plant. Cover the striga very lightly with fine soil.

When striga foliar symptoms are observed/ or the

/ This normally occurred two weeks after striga application.

first striga emergence occurs the pots should be ranked in order of size of sorghum plant, numbered and arranged in experimental order. The herbicides should be applied to a sub-block in 140 ml of water as a soil drench whenever foliar symptoms or striga emergence are observed in it.

The experiment should be terminated when at least one sorghum plant has headed and one striga plant has flowered. All sub-blocks should grow for the same period after treatment.

Observation

1. Germination date of each pot.
2. Treatment date of each sub-block.
3. Note for each pot the state of the sorghum and striga plants every week on Monday.

State	Sorghum	Striga
Dead or absent	D	-
♣ Striga symptoms	n.a.	♣
Vegetative	V	É
Head visible	H	n.a.
Flowering	A	F

4. At termination, determine the total aerial D.W. of sorghum

5. At termination, determine the total aerial D.W. of striga

6. On pots with striga state " - " only. Wash out the roots to confirm the presence or absence of striga.

7. Group photograph of median pots in each treatment.

Comment

The potting soil was obtained from a high fertility plot of a long term cotton experiment. This ensured a low natural striga infestation and permitted better early growth of the sorghum plants.

APPENDIX 4.1

Results of pot tests of herbicidal activity against Striga hermonthecа parasitising sorghum.

The phenol group

Name of herbicide	Observations			
Meditonerb acetate	Test variety	SK60	SK60	NK300
	Dosage #	1	3	3
3-methyl-2, 4-dinitro-	Effect rankits	.16	.13	-.53
6-t-butylphenylacetate	" sorghum D.M.%	15	-10	-64
	" striga "			-73

Testing of this material was terminated when a granular formulation became available for field testing

APPENDIX 4.2

The ether group

Name of herbicide	Observations			
Nitrofen	Test variety	SK60	B57	Not selective
	Dosage #	1	$\frac{1}{3}$	
2,4-dichlorophenyl-4-nitrophenyl ether	Effect rankits	-.21	-.52	
	" sorghum D.M.%	-30	-37	
	" striga "		31	
C9122	Test variety	A189		Selective
	Dosage #	$\frac{1}{3}$		
3,5-dibromo-4-hydroxy-benzaldoxime-O-2',4'-dinitrophenylether	Effect rankits	.73		
	" sorghum D.M.%	6		
	" striga "	-52		

APPENDIX 4.3

The nitrile group

Name of herbicide	Observations	
Chlorthiamid	Test variety	B57
	Dosage #	$\frac{1}{3}$
2,6-dichlorothiobenz-	Effect rankits	.11
amide	" sorghum D.M.%	-22
	" striga "	-91

The positive rankit effect indicated that the material was selective in spite of a small depression in dry matter production.

A granular formulation was therefore field tested.

APPENDIX 4.4

The phenoxyacetic acid group

Name of herbicide	Observations			
2,4-D	Test variety		SK60	NK300	B57
	Dosage #		$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$
2,4-dichlorophenoxyacetatic acid	Effect	rankits	.96	.20	-1.30
	"	sorghum D.M.%	13	100	-62
	"	striga "		-81	-59

This material was already known to be active against striga but it was used to assess the procedure. The results illustrate the variable toxicity of 2,4-D to sorghum varieties.

The phenoxyacetic acid group (contd.)

Name of herbicide	Observations		
MCPA . .	Test variety	NK300	B57
	Dosage #	10	$\frac{1}{3}$
4-chloro-2-methyl	Effect rankits	-.09	-.85
phenoxy-acetic	" sorghum D.M.%	12	-39
acid	" striga "	0	4

MCPA is better tolerated by sorghum than 2,4-D. (The 10 lb. dosage was applied in error) but is not active enough against striga.

2,4,5-T	Test variety	SK60	SK60	SK60	NK300
	Dosage #	1	3	9	9
2,4,5-trichloro-	Effect rankits	-.22	-.78	.30	-.14
phenoxy-acetic	" sorghum D.M.%	-77	-42	13	-12
acid	" striga "				+4

2,4,5-T is better tolerated than MCPA but less toxic to striga.

The phenoxyacetic acid group (contd.)

Name of herbicide	Observation			
2,4-DES	Test variety	SK60	SK60	NK300
	Dosage #	1	1	1
Na-2(2,4-dichloro-	Effect rankits	.86	.51	-.61
phenoxy) ethyl	" sorghum D.M.%	-12	-6	-53
sulphate	" striga "			0

As might be expected, this material behaves similarly to 2,4-D which is produced when 2,4-DES is hydrolysed.

APPENDIX 4.5

Phenoxy propionic acid group

Name of herbicide	Observation		
Mecoprop	Test variety	NK300	Similar to 2,4-D
	Dosage #	$\frac{1}{3}$	
2-(4-chloro-2-	Effect rankits	-.20	
methyl-phenoxy)	" sorghum D.M.%	-26	
propionic acid	" striga "	-45	

Phenoxybutyric acid group

MCPB	Test variety	SK60	NK300	Similar to
	Dosage #	1	1	MCPA
4-(4-chloro-2-	Effect rankits	-.27	-.18	
methyl phenoxy)	" sorghum D.M.%	-67	-10	
butyric acid	" striga "		-58	

Phenoxy propionic acid group (contd.)

Name of herbicide	Observation		
2,4-DB	Test variety	B57	Apparently not
	Dosage #	$\frac{1}{3}$	active against
4-(2,4-dichloro-	Effect rankits	-.61	striga and depresses
phenoxy) butyric	" sorghum D.M.%	-64	sorghum growth.
acid	" striga "	11	

APPENDIX 4.6

Benzoic and phenylacetic acids

Name of herbicide	Observation	
2,3,6-TBA	Test variety	B57
	Dosage #	$\frac{1}{3}$
2,3,6-trichloro-	Effect rankits	-.50
benzoic acid	" sorghum D.M.%	-25
	" striga "	-75

2,3,6-TBA was not selective at this dosage. Testing was stopped because field testing of this material was started on the basis of its reported activity against Striga asiatica in Carolina.

Benzoic and phenylacetic acids (contd.)

Name of herbicide	Observation					
Chloramben	Test variety		SK60	SK60	NK300	A189	B57
	Dosage #		1	1	1	$\frac{1}{3}$	$\frac{1}{9}$
3-amino-2,5-	Effect	rankits	.76	-.18	-.45	-1.26	.51
dichloro-benzoic	"	sorghum D.M.%	12	-36	-39	-93	284
acid	"	striga "					-54

This material did not give consistent results in pot tests even though it appeared to be selective at a dosage of $\frac{1}{9}$. A granular formulation was tested in the field.

Chlorfenac	Test variety		SK60	NK300
	Dosage #		1	1
2,3,6-trichloro-	Effect	rankits	.60	-.11
phenyl acetic	"	sorghum D.M.%	-68	-12
acid	"	striga "		-100

Reported to be selective against Striga asiatica in maize but appears to be too toxic to sorghum in pot tests.

APPENDIX 4.7

Halogenated aliphatic acids

Name of herbicide	Observation			Not selective
TCA	Test variety	B57	A189	
	Dosage #	$\frac{2}{3}$	$\frac{1}{3}$	
Trichloracetic acid	Effect rankits	.06	-.22	
	" sorghum D.M.%	-38	-29	
	" striga "	-58	-29	
Dalapon	Test variety	SK60	B57	Not selective
	Dosage #	1	$\frac{1}{9}$	—
2,2-dichloropro-pionic acid	Effect rankits	-.97	-.36	
	" sorghum D.M.%	-91	-49	
	" striga "		-44	

APPENDIX 4.8

Carbamates

Name of herbicide	Observation			
Chlorbufam	Test variety		NK300	This material appeared to
	Dosage #		$\frac{1}{3}$	have definite activity
1-methylprop-2-	Effect rankits		.18	against striga and was
ynyl N-(3-chloro-	"	sorghum D.M.%	-5	scheduled for field testing.
phenyl)-carbamate	"	striga "	0	No granular formulation has yet been obtained.

MB 8882	Test variety		B57	A189
	Dosage #		$\frac{1}{3}$	$\frac{1}{9}$
methyl N-(4-nitro-	Effect rankits		-.25	-.27
benzene sulphonyl)	"	sorghum D.M.%	-19	42
carbamate	"	striga "	24	-18

Testing indicates moderate selectivity at low dosages.

Carbamates (contd.)

Name of herbicide	Observation		
Chlorpropham	Test variety	B57	Chlorpropham is selective at the dosage tested and will be field tested
	Dosage #	$\frac{1}{3}$	
iso-propyl N-(3-chloro-phenyl) carbamate	Effect rankits	.21	
	" sorghum D.M.%	132	
	" striga "	-90	

C 10725	Test variety	B57	A189
	Dosage #	$\frac{2}{3}$	$\frac{1}{3}$
4-cyano-2,6-diido-phenyl-N-methyl-carbamate	Effect rankits	-.17	-.16
	" sorghum D.M.%	-48	7
	" striga "	- 2	0

After testing had commenced, the manufacturers reported the acute oral LD 50 (rat) as 175 mg/kg. This was well below the arbitrary standard of 1000mg/kg set for acceptance into these tests. The material has therefore been discarded.

APPENDIX 4.9

Thiocarbamates

Name of herbicide	Observation			
Sulphallate	Test variety	B57	A189	At $\frac{1}{3}$ # sulphallate
	Dosage #	$\frac{2}{3}$	$\frac{1}{3}$	was moderately
2-chloroallyl N	Effect rankits	-.22	.18	selective and
N-diethyl (dithio-	" sorghum D.M.%	-8	61	will be field
carbamate)	" striga "	96	-40	tested.
EPTC	Test variety	NK300	B57	Very toxic to
	Dosage #	$\frac{1}{3}$	$\frac{1}{9}$	sorghum. Selec-
S-ethyl N N-dipropyl	Effect rankits	-.42	-.55	tivity at lower
(thiocarbamate)	" sorghum D.M.%	-74	-17	dosages not yet
	" striga "	-100	-95	determined.

Thiocarbamates (contd.)

Name of herbicide	Observation		
Pebulate	Test variety	NK300	Similar to EPTC
	Dosage #	$\frac{1}{3}$	
S-propyl N-butyl	Effect rankits	-.04	
-N-ethyl (thio-	" sorghum D.M.%	-25	
carbamate)	" striga "	-56	

Vernolate	Test variety	SK60	SK60	B57
	Dosage #	1	1	$\frac{1}{3}$
S-propyl N N-di-	Effect rankits	-.76	-1.08	+.44
propyl-(Thiocar-	" sorghum D.M.%	-67	-43	0
bamate)	" striga "			58

This material was repeatedly tested because it was seen to control striga shortly after application. The condition of the host plants deteriorated towards the end of each test apparently because of herbicidal breakdown. No practical value.

Thiocarbamates (contd.)

Name of herbicide	Observation	
Tri-allate	Test variety	A189
	Dosage #	$\frac{1}{3}$
S-2,3,3-trichloro-	Effect rankits	-.42
allyl N N-diisopropyl-	" sorghum D.M.%	41
(thiocarbamate)	" striga "	54

Not selective on the results of this trial. Higher dosages are toxic to sorghum. The 1969 field screening test indicated that it was selective at a much lower dosage.

APPENDIX 4.10

Amides

Name of herbicide	Observation			
Propachlor	Test variety		SK60	Completely inactive
	Dosage #		1	against striga.
2-chloro-N-iso-	Effect rankits		-.57	
propyl-N-phenyl-	"	sorghum D.M.%	-42	
acetamine	"	striga "		
CP 50144	Test variety		B57	Definitely not active
	Dosage #		$\frac{1}{3}$	against Striga
2-chloro-N-2,6-	Effect rankits		0	hermontheca in pot
diethyl-phenyl-N-	"	sorghum D.M.%	-18	tests.
methoxymethyl-	"	striga "	1811	
acetamide				

Amides (contd.)

Name of herbicide	Observations				
Difenamid	Test variety	SK60	MK300	B57	B57
	Dosage #	1	3	1	3
N N-dimethyl-di-	Effect rankits	1.22	-.46	-.10	-.02
phenylacetamide	" sorghum D.M.%	23	18	10	16
	" striga "	-	-54	-69	-92

The first test of this material indicated useful activity but this could not be confirmed in later tests. A granular formulation will be field tested when available.

APPENDIX 4.11

The substituted urea group

Name of herbicide	Observation						
Chloroxuron	Test variety		SK60	NK300	The results obtained with this material were not consistent enough to justify field testing.		
	Dosage #		1	1			
N^1-4-(4-chlorophenoxy) pheny-NN-dimethylurea	Effect	rankits	1.24	-.57*			
	"	sorghum D.M.%	-64	16			
	"	striga "		-79			
Chlorbromuron	Test variety		SK60	SK60	SK60	B57	B57
	Dosage #		1	1	3	$\frac{1}{3}$	1
N^1-(4-bromo-3-chlorophenyl)-N-methoxy-N-methyl-urea	Effect	rankits	-.81	.08	.51	-1.33	-.18
	"	sorghum D.M.%	-78	-11	.16	-67	-19
	"	striga "				-13	71

This material is recommended for pre-emergence weed control in sorghum but the results do not indicate that it is well tolerated by sorghum or active against striga.

The substituted urea group (contd.)

Name of herbicide	Observation						
Fluo-meteron	Test variety		SK60	SK60	B57	B57	A189
	Dosage #		1	3	$\frac{1}{3}$	$\frac{1}{9}$	$\frac{1}{27}$
N^1-(3-trifluoro-	Effect	rankits	-.55	-.59	-1.50	-.87	.31
methylphenyl)-NN	"	sorghum D.M.%	-68	-35	-62	-46	191
dimethylurea	"	striga "			12		132

At dosages which were well tolerated by sorghum this herbicide was insufficiently active against striga.

Metobromuron	Test variety		SK60	SK60	B57
	Dosage #		1	3	1
N'-(4-bromophenyl)	Effect	rankits	-.29	1.66	-.31
-N-methoxy-N-	"	sorghum D.M.%	-73	64	-75
methylurea	"	striga "			25

The second test of this material gave very strong evidence of toleration by sorghum under a light striga infestation. This could not be reproduced under heavier striga attack with a more susceptible variety.

The substituted urea group (contd.)

Name of herbicide	Observation			
Linuron	Test variety	SK60	SK60	B57
	Dosage #	1	3	1
N'-(3,4-dichlor-	Effect rankits	1.48	-1.70	.09
phenyl)-N-methoxy-	" sorghum D.M.%	31	-97	-50
N-methyl urea	" striga "			

This herbicide gave very variable results in pot tests but appears to have some selective contact activity. See Chapter 9.

Monuron	Test variety	SK60	NK300	NK300
	Dosage #	1	1	1
N'-(4-chlorophenyl)	Effect rankits	.53	-1.56	-.07
-N N - dimethylurea	" sorghum D.M.%	-4	-94	9
	" striga "		-97	-80

This material definitely possesses activity against striga but is probably not selective enough. A granular formulation will be field tested when available.

The substituted urea group (contd.)

Name of herbicide	Observation			
Buturon	Test variety		SK60	MK300
	Dosage #		1	$\frac{1}{3}$
N'-(4-chloro-	Effect	rankits	-.41	-.24
phenyl)-N-isobuty-	"	sorghum D.M.%	-13	68
nyl-N-methylurea	"	striga "		-7

Slightly selective. Will be rescreened in the field.

Fenuron	Test variety		B57	
	Dosage #		1	
NN-dimethyl-N'-	Effect	rankits	-.17	
phenylurea	"	sorghum D.M.%	-49	
	"	striga "	9	

Not selective at this dosage and does not appear to control striga.

The substituted urea group (contd.)

Name of herbicide	Observation	
Noruron	Test variety	A189
	Dosage #	$\frac{1}{3}$
N'-(hexahydro-4,7-	Effect rankits	.30
methan oindan-5-	" sorghum D.M.%	-20
yl)-NN-dimethylurea	" striga "	-86

This herbicide is recommended for weed control in sorghum and will be field tested when a granular formulation is obtained. The only completed test does not indicate marked selectivity.

APPENDIX 4.12

Diazines

Name of herbicide	Observation			
Pyrazon	Test variety		A189	An active but not very
	Dosage #		$\frac{1}{3}$	persistent material
5-amino-4-chloro-	Effect	rankits	1.48	which must be fully
2-phenylpyradizin-	"	sorghum D.M.%	669	field tested.
3(2H)-one	"	striga "	118	

Lenacil	Test variety		B57	A189	A189	Lenacil is
	Dosage #		1	$\frac{1}{3}$	$\frac{1}{9}$	not
3-cyclohexyl-5,	Effect	rankits	-.12	-.25	-.42	selective.
6-trimethylene-	"	sorghum D.M.%	-50	-19	-28	
uracil	"	striga "	-85	24	19	

Diazines (contd.)

Name of herbicide	Observation		
Bromacil	Test variety		B57
	Dosage #		1
5-bromo-6-methyl-	Effect rankits		.20
3-s-butyluracil	" sorghum	D.M.%	-31
	" striga	"	-85

Bromacil is active against striga and apparently less toxic to sorghum than lenacil in pots. It was listed for widespread field testing if a granular formulation became available.

Maleic hydrazide	Test variety		A189	Rather unexpectedly this
	Dosage #		$\frac{1}{3}$	grass growth inhibiter
1,2-dihydropyrid-	Effect rankits		.48	appears to have some
azine-3,6-dione	" sorghum	D.M.%	76	activity against striga
	" striga	"	183	but the effect does not
				persist.

APPENDIX 4.13

The triazine group

Name of herbicide	Observation			
Atrazine	Test variety	SK60	SK60	NK300
2-chloro-4-	Dosage #	1	3	3
ethylamino-6-	Effect rankits	-.30	.45	.85
isopropylamino-	" sorghum D.M.%	-74	18	-19
1,3,5-triazine	" striga "			-76

Atrazine is active against striga. It reduces emergence and kills a proportion of the emerged striga as well. Nigerian races of sorghum appear to tolerate it at normal herbicidal doses.

Ametryne	Test variety	SK60	SK60	NK300	B57	A189
2-methylmercapto-	Dosage #	1	3	3	$\frac{1}{9}$	$\frac{1}{27}$
4-ethylamino-6-	Effect rankits	.19	.32	-.27	-.18	.94
iso-propylamino-	" sorghum D.M.%	-72	16		29	398
-5-triazine	" striga "				-85	-58

Ametryne which was toxic to sorghum at normal herbicidal doses was spectacularly selective at very low doses. It may be insufficiently persistent for soil application in the field.

The triazine group (contd.)

Name of herbicide	Observation				
Prometryne	Test variety		SK60	SK60	Prometryne is toxic
2-methylmercapto-	Dosage #		1	3	to sorghum and
-4,6-bisiso-	Effect	rankits	-.15	-.22	apparently not active
propylamino-	"	sorghum D.M.%	-77	-6	against striga.
-s-triazine	"	striga "			

Propazine	Test variety		SK60	SK60	NK300
2-chloro-4,6-	Dosage #		1	3	3
-bisisopropyl-	Effect	rankits	-.95	-.18	-.23
amino-1,3,5-	"	sorghum D.M.%	-.77	3	-68
triazine	"	striga "			

In pots, propazine appeared to be inactive against striga and depressed sorghum growth.

The triazine group (contd.)

Name of herbicide	Observation				
Simazine	Test variety		SK60	NK300	B57
	Dosage #		1	3	3
2-chloro-4, 6-	Effect rankits		.99	-.87	-.12
bisethyl-amino-	"	sorghum D.M.%	19	-70	-61
1,3,5 - triazine				7	6

Simazine depresses sorghum growth and does not appear to be active against striga.

Methoprotyne	Test variety		B57	A189	Results are conflicting
2-isopropyl-	Dosage #		$\frac{1}{3}$	$\frac{1}{9}$	but it is almost
amino-4(3-meth-	Effect rankits		.22	-.49	certainly not selective
oxypropyl amino)	"	sorghum D.M.%	-57	-21	enough.
-6-methyl thio-1,	"	striga "	-68	0	
3,5 - triazine					

The triazine group (contd.)

Name of herbicide	Observation			
GS 14260	Test variety		B57	A189
	Dosage #		$\frac{2}{3}$	$\frac{1}{3}$
2-ethylamino-4-	Effect rankits		.08	.15
methylthio-6-t-	"	sorghum D.M.%	41	-11
butylamino-1,3,	"	striga "	153	49
5-triazine				

Moderately selective. The material should have been tested at a higher dosage in the second test. The lower dosage used was due to an operational error.

APPENDIX 4.14

Miscellaneous group

Name of herbicide	Observation					
Chlorthal	Test variety	SK60	SK60	NK300	B57	Not selective.
	Dosage #	1	1	1	$\frac{1}{3}$	
dimethyl 2,3,5,6-	Effect rankits	-.14	-.24	-.30	-.21	
tetrachloro-tere-	" sorghum D.M.%	-47	-35	-83	100	
phthalate	" striga "			-100	0	

Trifluralin	Test variety	SK60	NK300	B57	Too toxic to sorghum.
	Dosage #	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{9}$	
2,6-dinitro-NN-	Effect rankits	.55	-.56	-.60	
dipropyl-4-trifluoro	" sorghum D.M.%	41	-33	-64	
-methyl aniline	" striga "		-65	-100	

Miscellaneous group (contd.)

Name of herbicide	Observation				
D263	Test variety	SK60	SK60	NK300	B57
	Dosage #	1	1	3	1
4,6-diisopropyl-1,	Effect rankits	.13	-.16	-.32	-.51
1-dimethyl-5-pro-	" sorghum D.M.%	17	-19	-59	100
pionylindane +7-	" striga "			-100	-100
propionyl isomer					

The herbicide appears to be active against striga but delays sorghum maturity in pots. It was therefore nominated for field testing in order to evaluate the latter characteristic.

Flurenol	Test variety	B57	A189	This is an active mat-
	Dosage #	$\frac{1}{3}$	$\frac{1}{9}$	erial which needs to
butyl 9-hydroxy-	Effect rankits	-.74	.66	be tested at an even
fluorene-9-	" sorghum D.M.%	-23	5	lower dosage to measure
carboxylate	" striga "	-100	-98	its potential selectivity.

Miscellaneous group (contd.)

Name of herbicide	Observation			
Chlorfurecol	Test variety		B57	Testing not complete.
	Dosage #		$-\frac{1}{3}$	
methyl 2-chloro-	Effect rankits		-1.34	
9-hydroxy-fluorene	"	sorghum D.M.%	1	
-9-carboxylate	"	striga "	-100	

C9122	Test variety		B57	A189
	Dosage #		$\frac{1}{3}$	1
3,5-dibromo-4-hyd-	Effect rankits		.77	-.15
roxy-bezaldoxine O-2'	"	sorghum D.M.%	6	2
4'dinitro-phenylether	"	striga "	-52	38

C9122 was definitely selective at $\frac{1}{3}$ lb. dosage but the higher dosage retarded sorghum maturity and did not reduce striga growth.

Miscellaneous group (contd.)

Name of herbicide	Observation				
Nitralin	Test variety			A189	Nitralin is a very selective
	Dosage #			$\frac{1}{3}$	material which will be
4-(methyl sulph-	Effect	rankits		1.73	field tested when a
onyl)-2,6-dinitro	"	sorghum	D.M.%	3.66	granular formulation is
-N,N-dipropyl	"	striga	"	-39	available.
aniline					

APPENDIX 4.15

Manufacturers' samples tested under code. Active ingredient not yet disclosed

Name of herbicide	Observation			
GS13529	Test variety	B57	A189	Selective.
	Dosage #	$\frac{2}{3}$	$\frac{1}{3}$	Will be field tested.
	Effect rankits	-.45	.43	
	" sorghum D.M.%	10	28	
	" striga "	58	28	
C3470	Test variety	B57	A189	Selective but not persistent enough to control striga late in the crop. Possibly useful for controlling grass weeds and associated striga in other crops.
	Dosage #	$\frac{1}{3}$	1	
	Effect rankits	.62	.08	
	" sorghum D.M.%	50	6	
	" striga "	238	108	

Manufacturers' samples tested under code. (contd.)

Name of herbicide	Observation			
GES1798	Test variety	B57	A189	Shows useful selectivity
	Dosage #	$\frac{1}{3}$	1	at $\frac{1}{3}$ lb. dosage but is
	Effect rankits	.44	-1.50	very toxic to sorghum at
	" sorghum D.M.%	33	-99	1 lb. dosage. It will
	" striga "	-48		be field tested.
GES2079	Test variety	B57	A189	Results are conflicting
	Dosage #	$\frac{2}{3}$	$\frac{1}{3}$	and the material will
	Effect rankits	.23	-1.49	not be field tested.
	" sorghum D.M.%	0	-90	
	" striga "	-98	8	
GS13529	Test variety	B57	A189	Selective.
	Dosage #	$\frac{2}{3}$	$\frac{1}{3}$	Will be field tested.
	Effect rankits	-.45	.43	
	" sorghum D.M.%	10	28	
	" striga "	58	28	

APPENDIX 5.

Specimens of Computer Output

(1) Computer output. Ranking coefficients

PROGRAM PARB (PROGRAMMER J. OGBORN)

EXPERIMENT NO.AM2(67)R68 PT 18

AM2(67)R68 PT18 LOG 10 TR. RANKITS

DATA VALUES

-0.030	-0.240	-0.340	0.840	0.520	0.340	-1.190
-1.310	-0.580	0.290	0.180	-0.770	0.580	1.090
1.090	1.440	-1.840	1.840	-0.290	-1.440	-1.090
0.640	-1.610	0.460	0.080	-0.700	1.000	0.400
0.240	0.130	-0.920	-0.840			

ANALYSIS OF VARIANCE	D.F.	S.S.	M.S.
REPLICATIONS	2	2.8594	
TREATMENTS	15	17.0971	
BLOCKS	9	4.7539	0.528215
EFFECTIVE ERROR	21	21.4483	1.021350
RANDOMISED BLOCKS ERROR	30	26.2023	0.873409

CONVERSION FACTOR = 1.0000

RANKED ADJUSTED TREATMENTS

NUMBER	MEAN
11	1.1900
5	0.9367

NUMBER	MEAN
14	0.7233
7	0.5533
1	0.4367
15	0.1200
9	-0.0333
6	-0.0600
4	-0.0900
8	-0.2300
2	-0.2400
3	-0.4267
16	-0.5433
12	-0.5467
10	-0.7333
13	-0.9667

EFFECTIVE ERROR OF DIFFERENCE OF 2 MEANS

IN SAME BLOCK ±- 0.825167

IN DIFFERENT BLOCKS ±- 0.825167

(AS RANDOMISED BLOCKS) ±- 0.763068

EFFICIENCY = 83.4 PER CENT.

(2) Computer output. Sorghum dry matter yield

PROGRAM PARB (PROGRAMMER J. OGBORN)

EXPERIMENT NO.AM2(67)R68 PT18

AM2(67)R68 PT18 SORG. DM.G/POT

DATA VALUES

0.610	0.990	0.680	1.290	2.580	1.600	0.027
0.024	0.280	1.590	0.390	0.030	4.560	1.480
2.440	2.490	0.014	1.780	1.380	0.022	0.031
5.830	0.018	1.910	2.000	0.140	5.320	2.960
6.660	2.940	0.068	0.120			

ANALYSIS OF VARIANCE

	D.F.	S.S.	M.S.
REPLICATIONS	2	11.3333	
TREATMENTS	15	84.5891	
BLOCKS	9	18.5123	2.056920
EFFECTIVE ERROR	21	86.1901	4.104290
RANDOMISED BLOCKS ERROR	30	104.7024	3.490079

CONVERSION FACTOR = 1.0000

RANKED ADJUSTED TREATMENTS

NUMBER	MEAN
5	5.4333
14	3.4633
11	3.2900
9	2.7141

NUMBER	MEAN
1	2.1967
8	2.0592
3	1.7400
4	1.6945
7	1.6733
6	1.2467
13	0.9937
15	0.7433
16	0.7067
12	0.5802
2	0.5668
10	0.1707

EFFECTIVE ERROR OF DIFFERENCE OF 2 MEANS

IN SAME BLOCK ±- 1.654144

IN DIFFERENT BLOCKS ±- 1.654144

(AS RANDOMISED BLOCKS) ±- 1.525359

EFFICIENCY = 83.0 PER CENT.

(3) Computer output. Striga dry matter yield

PROGRAM PARB (PROGRAMMER J. OGBORN)

AM2(67) R68 PT18 STR.WT. LOG 10

DATA VALUES

-3.670	-1.340	-0.890	-1.720	-0.910	-0.340
0.000	0.000	0.070	-1.350	0.000	-1.150
-1.820	-2.480	0.000	0.000	-1.330	0.000
-1.220	0.000	0.390	0.000	0.000	-1.900
0.000	-0.650	0.000	0.000		

MISSING PLOT VALUES

PLOT	VALUE
7	-1.0379
12	-0.2246
13	-0.4946
16	-2.0796
25	-0.8087
28	-1.2672
29	0.2853
31	-1.0122
35	-0.4481
38	-2.4929
42	-0.8130
43	-1.3980

PLOT	VALUE
47	0.1877
48	0.4684

ANALYSIS OF VARIANCE

	D.F.	S.S.	M.S.
REPLICATIONS	2	1.3657	
TREATMENTS	15	23.4677	
BLOCKS	9	7.3767	0.819630
EFFECTIVE ERROR	7	6.5582	0.936879
RANDOMISED BLOCKS ERROR	16	13.9348	0.870927

CONVERSION FACTOR = 1.0000

RANKED ADJUSTED TREATMENTS

NUMBER	MEAN
12	0.2699
10	-0.0108
7	-0.2808
6	-0.5600
8	-0.6465
5	-0.6733
13	-0.8240
16	-1.0115
3	-1.0276
14	-1.1800

NUMBER	MEAN
11	-1.2267
9	-1.2825
1	-1.3567
4	-1.5965
2	-1.8657
15	-2.6914

EFFECTIVE ERROR OF DIFFERENCE OF 2 MEANS

IN SAME BLOCK +- 0.790308

IN DIFFERENT BLOCKS +- 0.790308

(AS RANDOMISED BLOCKS) +- 0.761983

APPENDIX 6

Summary of observations from combined activity test 1969

Herbicide name	Contact activity dosage	Soil activity (complete suppression of emergence) Dosage #	Duration weeks	Selectivity ratio
Standard materials				
Ametryne	1.1	4.0	6	2.9
Linuron	7.6	4.0	1	2.9
MCPA	0.22	0.28	2	40.6
MCPB	0.61 (on mature striga)	0.49	2	23.3
2.4-D	None (on mature striga)	3.3	3	3.5
Quaternary ammonium compounds				
Diquat	None (on mature striga)	N.A.	N.A.	N.A.
Benzoic and phenylacetic acids				
Chloramben	0.27	9.3	1	1.2
Dicamba	2.0	5.0	2	2.3

Herbicide name	Contact activity dosage	Soil activity (complete suppression of emergence)		
		Dosage #	Duration weeks	Selectivity ratio
Thiocarbamates				
Sulphallate (incorporated)	N.A.	5.0	12	2.3
Tri-allate "	N.A.	0.027	6	288.5
Ureas				
Noruron	None	6.1	2	1.9
Diuron	None	7.1	2	1.6
Difenoxuron	None	7.6	2	1.5
Noruron-DSMA (1-3)	None	7.6	2	1.5
Buturon	None	6.1	2	1.9
Amides				
Cypromid	0.93	0.93	2	12.4
Chloretin	None	2.0	2	5.8
Chloretin-pyrazone (2.5-1)	0.21	2.0	2	5.8
Chloretin-oxypyrazone (3.3-1)	None	3.3	6	3.5
Ethers				
C6989	0.016	3.3	2	3.5

Herbicide name	Contact activity dosage	Soil activity (complete suppression of emergence)		
		Dosage #	Duration weeks	Selectivity ratio
Ethers				
C9122	5.0	None	-	-
Diazines				
Maleic Hydrazide	None	7.6	8	1.5
Bromacil	5.04	3.3	8	0.8
Lenacil	None	4.0	4	2.9
Anilines				
Nitralin	N.A.	0.027	10	288
Phenols				
Cresols	9.3	3.3	1	3.5
Phenoxy-propionic acids				
Mecoprop	2.5	1.1	2	10.1
Carbamates				
Chlorbufam/cycluron	6.2	4.0	3	2.9
Proxipham	None	1.4	3	8.2
MB8882	None	5.0	4	1.9
'Azak'	None	None	-	-
C10725	None	4.0	2	2.9

Herbicide name	Contact activity dosage	Soil activity (complete suppression of emergence)		
		Dosage #	Duration weeks	Selectivity ratio
Samples of undisclosed composition				
2725 Al	.027	.32	5	35.9
Triazines				
GES2079	None	1.4	3	8.2
GS 14260	None	9.3	1	1.2
GS 13529	None	9.3	1	1.2
Methoprotyne	None	9.3	1	1.0
Miscellaneous				
Benazolin	.88	2.5	2	4.6
Chlorthal	6.2	2.1	3	5.4
'Knoxweed'	6.2	.40	3	23.3
Chlormequat	None	7.6	6	1.5

APPENDIX 7

Table 1. Striga Control Sprays. Experiment AM14 (68)

The estimated volumes of herbicide applied periodically (gallons/acre)

Treatment	12/9	19/9	25/9	2/10	9/10	16/10	23/10	30/10	6/11		13/11
Ametryne	3.90	7.37	1.37	1.81	0.64	0.37	0.00	1.40	2.08	ab	1.42
MCPA	3.58	4.00	0.55	0.87	0.62	0.12	0.68	1.19	1.15	ab	0.56
Diquat	4.99	5.39	3.94	2.92	1.41	0.55	3.47	1.43	0.07	a	1.01
Fenac	2.74	3.91	2.49	2.55	2.31	2.84	0.65	1.78	1.25	ab	0.04
2,4,5-TPK	3.73	5.20	1.36	1.42	0.52	1.42	0.00	0.75	1.20	ab	0.96
Monuron	5.36	7.28	0.49	1.73	2.31	0.91	0.31	1.79	1.49	ab	0.79
Linuron	5.13	6.12	1.92	1.50	0.76	1.66	0.76	1.55	2.85	ab	2.57
Atrazine	3.35	5.63	1.73	1.73	1.02	0.23	1.03	1.13	1.17	ab	1.64
2m4-D(Na)	4.44	5.97	2.61	3.52	1.19	0.28	2.39	1.13	2.88	ab	2.22
Amitrol-T	5.10	9.50	2.17	1.50	1.19	2.08	2.00	1.96	1.86	ab	1.64
CMPP	3.34	4.30	1.78	0.95	1.49	0.69	0.96	0.96	0.90	a	0.71
Paraquat	3.22	2.30	1.70	2.61	0.89	0.24	1.33	4.85	2.03	ab	2.30
2,4,5-T	4.85	5185	1.18	2.00	0.21	0.25	1.66	0.00	4.91	b	0.19
Cypromid	5.21	5.50	2.20	1.55	0.99	1.10	3.99	2.86	2.93	ab	2.18
MCPB	4.28	3.48	1.34	1.96	0.67	2.78	1.61	3.93	3.83	ab	2.98
S.E.Diff(1) ±	1.735	±2.53	±1.250	±0.683	±0.875	±1.223	±1.171	±1.958	±0.984		±1.440
(2)	-	±2.62	-	±0.735	±0.928	-	±1.259	±2.012	-		-
Mean	4.21		1.78	1.91	1.08	1.03	1.39	1.78	2.04		1.41

APPENDIX 7

Table 2

The estimated cumulative volumes of herbicide applied periodically

Date	19/9	25/9	2/10	9/10	16/10	23/10	30/10	6/11	13/11
Treatment									
Ametryne	11.5	12.9	15.2	15.5	16.6	15.9	16.1	18.0	19.1
MCPA	7.9	8.5	9.0	9.3	9.6	9.7	11.4	12.6	13.4
Diquat	9.8	13.8	16.7	18.5	19.1	22.7	23.7	24.4	25,2
Fenac	6.3	8.8	11.0	13.6	16.1	16.5	18.6	19.8	19.6
2,4,5-TPK	9.0	10.3	12.3	12.8	14.8	14.3	13.6	14.8	15.7
Monuron	12.5	13.0	14.9	17.5	18.1	18.8	20.7	22.2	23.0
Linuron	10.5	12.5	13.6	14.6	15.8	16.3	18.4	21.3	24.0
Atrazine	9.2	10.9	12.8	13.8	14.2	14.9	16.0	17.1	18.8
2,4-D (Na)	10.5	13.1	16.7	17.5	17.9	20.5	21.3	24.2	26.4
Amitrol-T	14.3	16.5	17.4	18.4	20.1	21.6	24.4	26.2	28.0
CMPP	7.5	9.3	10.4	11.8	12.5	13.2	14.3	15.4	16.3
Paraquat	6.1	7.8	10.1	10.4	10.8	12.0	17.0	18.8	21.2
2,4,5-T	11.1	12.3	14.5	14.3	14.8	16.6	15.7	20.4	20.4
Cypromid	10.4	12.5	14.7	16.1	17.2	22.0	24.3	27.2	29.3
MCPB	7.3	8.7	10.7	11.7	14.0	16.0	20.3	24.3	27.5
S.E.diff.(1)	± 3.09	±3.07	±3.39	±3.27	±3.60	±4.32	±5.04	±5.67	±6.64
(2)	-	-	-	±3.36	-	±4.43	±5.27	±6.02	±6.93
Mean	9.59	11.39	13.33	14.39	15.44	16.73	18.39	20.45	21.86

APPENDIX 7

Table 3

The estimated number of 'green and turgid' striga treated at each application 1000s/acre

Date	21/8*	24/9	2/10	9/10	15/10	22/10	30/10	6/11	13/11
Treatment									
Ametryne	3.02	1.79	4.82	1.51	4.62	0.00	5.21	1.21	0.21
MCPA	1.21	1.99	2.31	2.09	2.05	2.15	1.55	0.30	0.30
Diquat	1.21	4.36	9.25	3.49	9.72	4.32	1.64	0.60	0.91
Fenac	0.91	2.58	5.06	1.62	0.48	0.82	0.43	0.60	0.18
2,4,5-TPK	1.82	1.17	4.16	3.49	1.56	0.00	1.18	0.60	0.00
Monuron	1.21	1.63	6.97	2.53	2.82	0.85	0.84	0.00	0.13
Linuron	2.13	3.67	3.14	1.74	4.13	1.29	1.48	2.18	0.87
Atrazine	2.72	2.72	1.17	2.52	0.18	1.93	0.27	0.00	0.00
2,4-D (Na)	0.91	1.39	7.48	4.60	4.16	7.20	0.00	0.00	0.78
Amitrol-T	2.42	1.24	3.17	2.40	8.10	4.37	1.71	0.60	0.18
CMPP	0100	1.09	2.27	2.03	1.71	1.50	1.01	0.60	0.69
Paraquat	0.91	2.30	3.89	2.53	5.71	1.81	3.77	1.51	0.00
2,4,5-T	2.72	1.82	2.44	0.55	0.00	0.98	0.00	0.91	0.08
Cypromid	1.51	3.41	5.12	2.89	5.41	5.25	2.96	1.51	0.56
MCPB	2.12	2.11	4.45	1.14	2.23	1.92	1.58	0.60	0.22
Untreated	0.91	2.41	5.39	3.91	7.41	4.40	1.21	1.21	0.13
S.E.of diff(1)	±1.534	±1.515	±3.275	±1.571	±3.353	±1.625	±2.034	±0.711	±0.500
(2)	-	±1.606	±3.457	±1.694	±3.550	±1.753	±2.139	-	±0.531
Treated Mean	1.65	2.22	4.38	2.34	5.53	2.29	1.59	0.74	0.35
S.E.diff. from Untreated	±1.20	±1.14	±2.46	±1.19	±2.52	±1.23	±1.52	±0.52	±0.38

APPENDIX 7

Table 4 The cumulative estimated number of 'green and turgid' striga treated at each application 1000s/acre

Date	24/9	2/10	9/10	15/10	22/10	30/10	6/11	13/11
Treatment								
Ametryne	5.2	7.8	8.8	13.1	11.6	18.3	19.6	19.4
MCPA	3.1	5.0	7.2	9.9	12.3	13.6	13.2	14.7
Diquat	5.4	14.5	17.8	27.2	31.2	38.1	38.4	39.2
Fenac	3.3	10.0	11.8	11.9	13.3	17.1	17.4	17.7
2,4,5-TPK	3.3	5.8	9.0	10.5	8.8	11.3	12.1	11.7
Monuron	2.8	11.5	14.2	16.6	17.8	18.0	17.8	18.0
Linuron	5.6	9.6	11.6	15.7	17.2	42.2	44.4	45.0
Atrazine	5.6	7.1	9.7	9.7	11.9	11.8	12.0	11.9
2,4-D (Na)	2.6	9.0	13.5	11.7	24.6	20.0	20.4	20.9
Amitrol-T	3.1	7.3	9.9	18.5	23.3	28.6	28.9	29.5
CMPP	1.3	3.1	5.2	7.1	8.7	5.2	6.3	7.5
Paraquat	3.2	6.0	8.5	14.7	16.3	20.0	21.6	21.5
2,4,5-T	4.8	6.9	7.4	6.9	8.7	8.2	9.1	9.1
Cypromid	5.0	9.9	12.6	17.7	22.6	26.6	27.9	28.3
MCPB	4.2	9.6	10.9	13.1	15.3	12.0	12.8	13.0
Untreated	3.0	9.4	13.5	21.4	26.1	26.8	27.8	28.3
S.E.of diff.(1)	±2.53	±3.20	±3.85	±6.50	±7.25	±11.23	±11.38	±11.45
(2)	±2.61	±3.46	±4.17	±7.02	±7.84	±12.06	±12.21	±12.30
Treated Mean	3.90	8.83	10.53	14.02	16.23	19.40	20.13	20.49
S.E.diff. from untreated	±1.88	±2.43	±2.93	±4.93	±5.51	±8.50	±8.51	±8.57

APPENDIX 7

Table 5 — Contact herbicide application 1968

Correlation of grain yield with striga emergence and value of herbicide applied

Date	21/8	12/9	19/9	25/9	2/10	9/10	16/10	23/10	30/10	6/11	13/11
Volume applied	NR										
Best transformation		Log 10	None	None	None	Square root	None	Reciprocal	Reciprocal	None	Reciprocal
F value		0.491	0.706	3.649	3.953	0.512	0.113	6.557*	3.920	0.891	1.385
Striga emergence		N.R.	N.R.								
Best transformation	Reciprocal			Square root	Square root	Square root	Square root	Cubic root	Reciprocal	Reciprocal	None
F value	1.177			0.740	2.670	2.004	0.291	6.544*	4.724*	0.343	0.070

N.R. = No Record

APPENDIX 8

BQ1 (67): Striga control 2,4-D granules evaluation trial.

OBJECT: To assess the value of a single application of 2,4-D formulated in granules for control of striga in sorghum.

DESIGN: 2^3 factorial with additional control plots
18 plots in 2 blocks of 9

TREATMENTS: 8 factorial combinations of:

2,4-D granules	
Nil	-
vs	
1 #	Dg
X	
Compound fertiliser 21-14-0	
Nil	-
vs	
1 cwt. per acre	F
X	
Time of application	
Treatments applied:	
Pre-sowing	E
vs	
After thinning	T

Crop: Sorghum, recommended local variety at recommended spacing.

Plot size: Gross 10 x 12 yards (10 x 36" ridges 12 yds. long 1/66.5 acres)
Net 8 x 10 yards (8 x 36" ridges 10 yds. long)
Please use the exact plot specified. The treatments supplied are weighed out for this plot size.

Soil sample: Make a composite sample of soil collected from the top six inches on every plot of the experiment before applying any striga or 'C' treatments.

Method of application:
Agronomy Section, Institute for Agricultural Research, will supply a pack containing the following:

18 numbered packets of striga infested soil. (Marked 'STRIGA'). 14 numbered packets containing the correct treatment for each plot. (Marked 'E' or 'T'). If possible, use a site which is known to have a heavy striga infestation. After preliminary site clearing, mark out the plots and broadcast the "STRIGA" packets

one on each plot of the experiment.

Before the ridges are finally prepared for sowing broadcast the packets marked 'E' on the correct plots. (The packets have the correct plot number on the label) Any light cultivation can be done after this or the granules can be left scattered on the soil surface. The 'T' treatment packets should be broadcast immediately after thinning the sorghum crop.

Observations required:

(1) Site history

(2) Germination stand count, supply once only.

(3) Stand count after thinning. (See Weed Control General Instructions)

(4) Final stand count at harvest

(5) Weed Control. Observe 'General Instructions', and the following additional procedure for the special weed striga:
(a) Record the number of striga plants flowering on each plot during each weekly weed score.
(b) Then remove the flowering striga (by hand-pulling) and dry in paper bags under cover for six days. Record the weight of

striga material taken from each plot. See 'General Instructions' for weighing procedure.

(c) After weighing, put the striga material on to a heap of dry soil under cover. The pulled striga from this and other experiments should be accumulated in this way for use as a source of striga infection in subsequent experiments.

(6) Weight of unthreshed heads

(7) Weight of threshed grain

(8) Weight of stalks

APPENDIX 9

CP3 (67) R68: Striga Control Powders

OBJECT: To assess the value of a single application of 2,4-D for control of striga in sorghum.

DESIGN: 2 x 6 factorial with 24 plots in 2 blocks of 12

SITE: Choose a site which grew sorghum in the previous season which is known to be infested with striga

TREATMENTS: 12 factorial combinations of:-

Fertiliser treatments	Symbol
Nil	-
vs	
21-14-0 compound fertiliser placed before sowing 1 cwt/acre	F

X

Herbicides treatments	
Nil	-
vs	
2,4-D granules, 1 # broadcast before sowing	DgE
vs	
21-14-0 compound fertiliser, 3 cwt/acre broadcast at thinning	NT

	Symbol
vs	
2,4-D granules, 1 # broadcast at thinning	DgT
vs	
Granulox B 1 # broadcast at thinning	BT
vs	
Granulox A, 1 # dusted on to emerged striga at first striga flower	AS

CROP: Sorghum, recommended local variety at 2' apart on 3' ridges

PLOT SIZE: Gross 8 x 8 yards = 1/75.6 acre

Net 6 x 6 yards = 1/134.4 acre

Please use the exact plot specified.

The treatments supplied are weighed out for this plot size.

SOIL SAMPLE: Make a composite sample of soil collected from the top six inches on every plot of the experiment before applying any treatments.

METHOD OF APPLICATION:

Fertiliser treatments.

Apply the fertiliser (2 bags marked 'F') according to the instructions for applying superphosphate in 'Recommended Practices for Guineacorn production',

Ministry of Agriculture RECOMMENDED PRACTICES No.2 to the 12 plots marked 'F' on the plan.

Herbicides treatments.

The treatment DgE (4 bags marked 'DgE') should be broadcast as evenly as possible on to the 4 plots marked 'DgE' on the plan one day before the sorghum is sown. Treatment NT, DgT and BT should be broadcast on the correct plots as evenly as possible immediately after the crop has been thinned. Avoid putting any herbicide down the funnel of the sorghum plant. As soon as the first pink striga flowers are seen on any plot of the experiment, the treatment AS (4 bags marked 'AS') should be applied to the four plots marked 'AS'. <u>All striga</u> plants on the plot should be lightly dusted with the herbicide powder. DO NOT USE ALL THE POWDER.

One week later any striga plants which are still healthy should be dusted again

with all the remaining powder. USE ONLY THE CORRECT BAG FOR EACH PLOT.
DO NOT MIX THEM UP!

SOWING: 24 bags (labelled STRIGA) of striga seed are provided. A 'pinch' (about enough to cover a penny) of this material should be put into each sowing hole with the sorghum seed. Any striga seed left over after sowing a plot should be broadcast as evenly as possible over the surface of the plot. Use one bag of striga seed per plot.

CULTIVATION: Use normal hand-weeding but record any obvious treatment effects on general weed control.

OBSERVATIONS REQUIRED:

(1) Site history

(2) Germination stand count on the net plots, supply once only.

(3) At first striga flower; record the number of striga infested sorghum plants in each net plot.

(4) Final stand count at harvest on the net plots.

(5) Weight of unthreshed heads per net plot

(6) Weight of threshed grains per net plot

(7) Weight of stalks per net plot

(8) Air dry weight of striga which has flowered on each net plot at harvest

(9) Air dry weight of striga which has not flowered on each net plot at harvest.

PACKING LIST FOR STRIGA CONTROL POWDERS EXPERIMENT

Treatment Symbol	Material	g product per plot	No.of bags	Label/ plot no.
F	21-14-0	672	12	f/
NT	21-14-0	2017	4	NT/
DgE	20% 2,4-D granules	30	4	DgE/
DgT	20% 2,4-D granules	30	4	DgT/
Granulox B	18.5% A + picloram	32	4	BT/
Granulox A	18.1% 2,4-D/MCPA	33	4	AS/
	Sieved striga trash	19)		
	Sieved striga seed	3)		
	Sieved soil	100)		

APPENDIX 10

AM9 (67) R68 Striga Control Powders

OBJECT: (1) To assess the value of single applications of auxin herbicides for control of striga in sorghum

(2) In addition to compare above with single application of fertilisers.

DESIGN: 3 x 4 factorial + 4 additional treatments, 16 treatments in all in simple lattice design (two replicates)

SITE: V2

TREATMENTS: The 12 factorial combinations of

2,4-D granules (acqua kleen) at

1 lb. a.i. per acre	= 30 g.	Dg

Granulox A (2,4-D, MCPA) at 1 lb.

a,i. per acre	= 35 g.	A

Granulox B (as A + picloram) at

1 lb. a.i. per acre	= 35 g.	B

X

Applied at four different stages:

Early pre-sowing	E
At thinning	T
At first sorghum head exsertion	S
At first striga flower	Fl

TREATMENTS: In addition at thinning

Nitrochalk 3 cwt. per acre 2016g. NT

Single superphosphate 3 cwt. per acre 2016g. PT

21-14-0 compound at 3 cwt. per acre 2016g. NPT

Untreated -

CROP: Sorghum Short Kaura at 1½' apart on 3' ridges (plus a pinch of striga at every stand.)

PLOT SIZE: Gross 8 x 8 yard = 1/75.6 acre

Net 6 x 6 yard = 1/134.4 acre

METHOD OF APPLICATION: All treatments to be broadcast. 'E' treatment will be incorporated. The remainder to be left on surface. Granulox A and B are to be broadcast by scattering through a 'baft' bag. Avoid putting herbicide or fertiliser down the funnel of the sorghum plants.

CULTIVATIONS: Normal handweeding and bullock cultivation with Unibar. No weed scores are required.

OBSERVATIONS REQUIRED:

1. Germination stand count on the net plot. Supply once only.
2. At first striga flower, record the number of striga infested sorghum plants in each net plot.
3. At first striga flower, record the number of striga stalks on each net plot.
4. Final stand count at harvest on the net plots.
5. Weight of unthreshed heads per net plot.
6. Weight of threshed grain per net plot.
7. Weight of sorghum stalks per net plot (by sample)
8. Air dry weight of striga which has flowered on each net plot by harvest.
9. Air dry weight of striga which has not flowered on each net plot at harvest.
10. the number of living (fresh, green turgid) stalks of striga on each net plot.

APPENDIX 11

AM10 (67) Striga Control High N

SITE: Western end of Section S9

DESIGN: Double 4 x 4 latin square (32 plots)

PLOT SIZE: Gross 8 x 8 yard

Net 6 x 6 yard

Crop spacing 3 x 1½ ft.

TREATMENTS:	Single supers	Nitrochalk	Symbol
g/plot	672/	Nil	0
	672/	672	1
	672/ + 672	1344	2
	672/ + 1344	2016	3

/ Applied pre-sowing, remaining treatments broadcast after thinning.

Note: Do not let broadcast fertiliser drop into the funnel of sorghum plants.

CROP: Sorghum: Short Kaura

WEEDING: Normal handweeding of ridges) until
Gramoxone + Simazine control of) striga
furrows.) emergence starts.

After striga emergence observe full weed control observations.

WEEKLY ROUTINE: Walk through the experiment looking for striga each week. On first observed emergence, commence full weed control observations.

BASIS OF EXPERIMENT: Stands of sorghum receiving adequate fertiliser in experiments often appear to have fewer striga plants than the untreated control.

This may be due to:

(a) cleaner weeding of fertilised plots (why?)

(b) greater competition by the crop for light or some other growth factor.

(c) a direct effect of high fertiliser in increasing the resistance of the sorghum plant to parasitisation.

(d) a direct effect on the striga.

Some American references to Striga asiatica in maize indicate that high fertiliser N has a direct effect on striga but Sudanese work on Striga hermonthecа in sorghum does not support this. The very high rates of N (69 lb/acre) will almost certainly be too high

for the variety and severe lodging may be expected. This will be reduced by applying the nitrogen after thinning.

The site is reputed to have a high natural level of striga infection. Light intensity measurements will be taken when striga starts to show through.

OBSERVATIONS REQUIRED:

1. Stand count after thinning.
2. Light intensity when striga plants first show above soil surface.
3. Number of striga plants flowering per plot.
4. Weight of striga plants removed at flowering.
5. Weight of grass weeds removed from plots after emergence of striga.
6. Weight of other weeds removed from plots after emergence of striga.
7. Yield of threshed grain.
8. Weight of heads.
9. Weight of stalks.

APPENDIX 12

AM10 (67) 68 Striga Control High N

SITE: Western end of Section S9

PLOT SIZE: Gross 8 x 8 yard or 7 x 8 yard (see plan)

Net 6 x 6 yard

DESIGN: Double 4 x 4 latin square (32 plots)

TREATMENT: Single supers	Nitrochalk	Symbol
g/plot 672/	Nil	0
672/ + 672	1344	1
672/ + 2016	2688	2
672/ + 3360	4032	3

/ Applied pre-sowing, remaining treatments broadcast at thinning.

Note: Do not let broadcast fertiliser drop into the funnel of the sorghum plant.

CROP: Sorghum: Short Kaura. Spacing, thin to 2 plants every 2 ft. Sow one pinch of striga seed per stand.

WEEDING: Normal handweeding of ridges as required. Inter-row cultivation of furrows after every handweeding using the Unibar cultivator.

RIDGE

PREPARATIONS: Ridge up using special toolbar after basal

single superphosphate has been spread.

Sow about a week later by hand.

Apply weed killer after sowing.

WEED KILLER: 2 pints of Gramaxone + ½ a.i. (= 1 lb. product of atrazine) = 18 ml of Gramaxone + 6 g. of Atrazine 50W per plot.

Applied post sowing/pre-emergent to sorghum.

WEEKLY ROUTINE: Walk through the experiment, look for striga each week.

OBSERVATIONS REQUIRED:

1. Stand count after thinning on each net plot.
2. Date of first observance of striga in each net plot.
3. Date of first observance of striga flower in each net plot.
4. Weight of sorghum heads per net plot at harvest.
5. Stand count at harvest.
6. Weight of sorghum stalks per net plot after harvest. (Take a 1/10 sample only)
7. Weight of threshed grain per plot.
8. Weight of striga (both living and dead) after harvest which has flowered.
9. Weight of striga which is still green and vegetative (i.e. has NOT flowered) per net plot after harvest.

APPENDIX 13

AM 12(67): Striga control, contact sprays

OBJECT: To measure activity of 25 herbicides against emerged striga.

SITE: Panel V2 New Extension, Samaru part sorghum observation lines Farafara x Combine Kaffir.

DESIGN: Originally 2 replicates of 25 minilog plots arranged in lattice but only one replicate was effective.

PLOT SIZE: 10 yard x 1 yard. 1 row of sorghum = 1 yard width of plot. No discards.

METHOD OF APPLICATION:

Apply one minilog run to the first 9 yard of a plot. Keep the jet as close to the sorghum as possible. Hold the jet at such a height that exactly 3 ft. are wetted by the spray. The striga plants have already emerged.

No.	Treatments	Formulation	Maximum #	Product/0.51
1	Morfamquat	20% wv.	0.75	4.2 ml
2	Paraquat	20% wv.	0.75	4.2 ml
3	Diquat	20% wv.	0.75	4.2 ml

METHOD OF APPLICATION (contd.)

No.	Treatments	Formulation	Maximum #	Product 0/51
4	2,4-D amine	30% wv.	3	10.4 ml
5	2,4,5-T	4% wv.	9	83.3 ml
6	MCPB	40% wv.	3	8.3 ml
7	2,4-DB	30% wv.	3	11.1 ml
8	MCPA	40% wv.	3	8.3 ml
9	Propachlor	65% w.p.	3	5.13g
10	Propanil	35% w.v.	3	9.5 ml
11	Atrazine	80% w.p.	3	4.17g
12	Propazine	50% w.p.	3	6.67g
13	Cypromid	24.4% wv.	3	13.7 ml
14	CMPP	30% w.v.	3	10.4 ml
15	Simazine	50% w.p.	3	6.67g
16	Fenac	18% w.v.	3	18.5 ml
17	Amitrole-T	24% w.v.	3	13.9 ml
18	Fluometeron	50% w.p.	3	6.67g
19	Linuron	50% w.p.	3	6.67g
20	"Glenbar"	75% w.p.	3	4.45g
21	Metabromuron	50% w.p.	3	6.67g
22	Chloroxuron	50% w.p.	3	6.67g
23	Monuron	80% w.p.	3	4.17g
24	Ametryne	50% w.p.	3	6.67g
25	2,4,5-TP/K	30% w.v.	3	11.1 ml

OBSERVATIONS REQUIRED:

All measurements to be in feet from the highest dosage end of the plot.

(1) Lowest dosage at which striga eventually dies.

(2) Weekly records of the highest dosage at which striga flowering is inhibited.

(3) Yield of sorghum grain per foot of row.

APPENDIX 14

DP16(68): Striga control sprays

OBJECT: To measure the effect of herbicide applications on striga infesting intercropped sorghum.

SITE: Choose a site which grew sorghum in the previous season which is known to be infested with striga.

DESIGN: 2 x 4 factorial, twice replicated.

PLOT SIZE: Gross 6 x 9 yard = 1/89.6 acres
Net 5 x 8 yard = 1/121 acres

TREATMENTS: 8 factorial combinations of:-

Fertiliser treatments	Symbol
Nil	-
21-14-0 compound fertiliser 1 cwt per acre placed before sowing	F

X

Herbicide treatments	
Nil	-
21-14-0 compound fertiliser 3 cwt. per acre broadcast at thinning	NT
Monuron 0.5 # sprayed at first striga flower	MS
Atrazine 0.5 # sprayed at first striga flower	Ats

CROP: Sorghum - recommended local variety at 2' spacing on the ridges, sown on alternate ridges.

Groundnuts - 1 row of the recommended local variety planted between two rows of sorghum on each net plot.

Cowpeas - 1 row of the recommended local variety planted between two rows of sorghum on each net plot. Each net plot contains 3 rows of sorghum interplanted with 1 row of groundnuts and 1 row of cowpeas. The single ridge discard row between net plots should be planted with the legume planted in the rows nearest to it in the net plots. See the field plan for details.

SOIL SAMPLE: Make a composite sample of soil collected from the top six inches on every plot of the experiment before applying any treatment.

METHOD OF APPLICATION:

Fertiliser treatments

Apply the fertiliser (8 bags marked 'F')

according to the instructions for applying superphosphate in 'Recommended practices for guineacorn production', Ministry of Agriculture RECOMMENDED PRACTICES No.2 to the 8 plots marked 'F' on the plan.
Apply to all the ridges in the gross plot.

Herbicide treatments

Treatment NT (4 bags marked 'NT') should be broadcast by hand on the correct plots as evenly as possible on the sorghum ridges immediately after thinning the sorghum.

Treatments MS and AtS should be sprayed onto the sorghum ridges using the sprayer and jet provided when the first pink striga flower is seen on any plot in the experiment.

Five bags are provided for each treatment one of which is marked 'PRIMER'. Dissolve all the powder in the PRIMER bag in half a bucket of water and pour into the sprayer. Spray onto waste ground until the sprayer sucks air. Then without emptying the

remaining solution from the sprayer add the herbicide for a treatment plot dissolved in half a bucket of water. Spray only the sorghum ridges in each plot as far as possible, though some spray drift onto the legumes is bound to occur.

SOWING: 16 bags (labelled STRIGA) of striga 'seed' are provided. A 'pinch' (about enough to cover a penny) of this material should be put into each sowing hole with the sorghum seed. Any striga seed left over after sowing a plot should be broadcast as evenly as possible on the surface of the sorghum ridges. Use one bag of striga seed/plot.

Sow the legume seeds at the recommended dates and spacings.

CULTIVATIONS: Use normal hand-weeding but record any obvious treatment effects on general weed control.

OBSERVATIONS REQUIRED:

(1) Site history.

(2) Germination stand on the net plots

OBSERVATIONS REQUIRED (contd.)

on all crops. Supply once only.

(3) At first striga flower, record the number of striga infested sorghum plants in each net plot.

(4) Record the stages of growth of the legume crops at first striga flower.

(5) Final stand count at harvest on the net plots on all crops.

(6) Weight of groundnut kernels.

(7) Weight of threshed cowpeas.

(8) Weight of threshed sorghum.

(9) Air dry weight of striga which has flowered on each net plot at harvest.

(10) Air dry weight of striga which has not flowered on each net plot at harvest.

APPENDIX 15

AM4(67)R68: Striga control Log screening trial

OBJECT: To assess the effect of nine herbicides applied with a minilog sprayer at 4 different stages of crop and parasite growth.

SITE: V2

DESIGN: 9 x 4 factorial in a 6 x 6 triple lattice. (3 fold replication). Plan 10.7 p.433.

TREATMENTS: The 36 factorial combinations of:-

Herbicide treatments	Max.dosage #	Symbol
2725 A1	6	1
Bromacil	3	2
2,4,5,TPK	6	3
2,4,5 TP MBE	6	4
Linuron	6	5
2,4-D	6	6
Meditonerb acetate	6	7
Fenac	3	8
Dicamba	3	9

X

Applied at four different times:-

Treatments (contd.)			Symbol
	Early pre-sowing	(25.5.68)	E 1
	At thinning	(15.6.68)	T 2
	At first sorghum head exsertion	(6.9.68)	S 3
	At first striga flower	(30.9.68)	F 4

CROP: Short Kaura or 'A lines' at 3 ft. in the row. Thin to 1 plant per stand.

PLOT SIZE: Gross 10 x 2 yard (2 ridges)

Net 10 x 1 yard (1 inter-row)

METHOD OF APPLICATION:

All treatments to be minilogged from 0-9 yard of plot, 1 yard being unsprayed. Minilog to be fitted with a flood jet so that both ridges of the plot can be sprayed by a flood jet with a vertical fan (3 ft. spread). The net inter-row should receive standard hand and bullock cultivations. The 'discard' inter-row should be kept clean by repeated dribble-bar application of paraquat.

OBSERVATIONS REQUIRED:

(1) Germination stand count and supply

OBSERVATIONS REQUIRED (contd.)

as often as necessary to establish 100% stand. Repeat stand count when re-supplying. Thin to 1 plant per stand.

(2) Weed score on each yard of each net inter-row whenever hand-weeding or cultivation is done.

(3) Stand count of sorghum before any herbicide application.

(4) Observation of emergence of striga at weekly intervals from 1st August.
(a) No. of striga stalks in each square yard of 'net inter-row'
(b) No. of striga stalks in flower/ sq. yard of 'net inter-row'.

(5) Total weight of sorghum plants (including head and stem but not roots) per sq. yard of inter-row.

(6) Total air dry weight of striga stalks still vegetative per square yard of inter-row.

(7) Total air dry weight of striga stalks

OBSERVATIONS REQUIRED (contd.)

which have flowered in each square yard of inter-row.

(8) Collect, dry and weigh the mature heads of sorghum in each sq. yard sub plot.

APPENDIX 16

AM 14(68): Striga control sprays.

OBJECT: To measure the effect of very low dosages of contact herbicides on striga infesting sorghum.

SITE: V2 - New Extension.

DESIGN: 16 treatments applied in a simple lattice design (2 replications). Plan 10.2 p.428 in Cochran and Cox.

PLOT SIZE: Gross 2 x 10 yard

Net 1 x 8 yard

TREATMENTS:

Material	Dosage #	Treatment no.
Atrazine	0.2	1
Fenac	0.3	2
2,4,5-T	0.2	3
Monuron	0.3	4
2,4,5-TPK	0.5	5
Diquat	0.2	6
Ametryne	0.2	7
Cypromid	0.4	8
CMPP	0.4	9
Linuron	0.3	10
2,4-D(Na salt)	0.2	11

Material	Dosage #	Treatment no.
MCPB	0.2	12
MCPA	0.2	13
Amitrole T	0.5	14
Paraquat	0.1	15
Untreated		16

CROP: Sorghum B lines "if available". Sow at 2 ft. spacing in the row. Add 1 pinch of striga seed per stand.

METHOD OF APPLICATION:

Use Minilog sprayer fitted up as a constant dosage sprayer to make all applications (Flood jet at low pressure). Apply first round of treatments when the first pink striga flower is seen on any plot of the experiment. Then examine weekly and 'spot' spray any surviving striga <u>which is in flower</u>. Measure the volume of solution used during the spot spraying on each plot.

BASAL FERTILISER:

1 cwt. of 21-14-0 compound = 227g per gross plot, placed at thinning.

OBSERVATIONS REQUIRED:

(1) Germination count on net plots. Supply once only.

(2) Date of first striga flower.

(3) At first striga flower, record the number of striga infested sorghum plants. (Use 'striga leaf' symptoms if in doubt).

(4) Count the total number of striga stems per plot at first striga flower.

(5) Final stand count at harvest on the net plots of sorghum.

(6) Count of surviving striga plants at harvest.

(7) Count of surviving striga plants in flower at harvest.

(8) Weight of unthreshed sorghum heads.

(9) Weight threshed sorghum grain.

(10) Weight of sorghum stalk.

(11) Oven dry weight of <u>surviving</u> striga at harvest which has <u>not</u> flowered.

(12) Oven dry weight of surviving striga at harvest which has flowered.

(13) The total amount of herbicide used on each plot.

OBSERVATIONS REQUIRED (contd.)

(14) Collect, dry and weigh any mature sorghum heads in a plot.

(15) 21.9.68: Record <u>new</u> striga emergences per plot on the day before spraying each week.

APPENDIX 17

AM6(67)R68: Striga control Log screening trial.

OBJECT: To measure the post-emergent contact activity of 30 selected herbicides against Striga hermontheca.

SITE: V2

DESIGN: 5 x 6 rectangular lattice (Plan 10.12 in Cochran and Cox p.435)

TREATMENTS: Thirty log screened plots of following:-

No.	Material	Maximum dosage #	Amount required g/1½ litre
1	Norea	3 80% wp	4.17
2	Azak	3 80% wp	4.17
3	Diquat	¾ 20%	4.2 ml
4	Urea + wetter	170 100%	189g+0.5ml wetter
5	Lenacil	1 80% wp	1.39g
6	Bromacil	1 80% wp	1.39g
7	Chloroxuron+wetter	3 50% wp	6.67g+0.5ml wetter
8	C6313 + wetter	3 50% wp	6.67g+0.5ml "
9	Morfamquat + wetter	¾ 20%	4.2 ml
10	Difenamid	3 80% wp	4.17
11	Sindone A	3 22.5% ec	14.8 ml
12	Sindone B	3 22.5 ec	14.8 ml

No.	Material	Maximum dosage #		Amount required g/1½ litre
13	Amiben	3	23% ec	14.5
14	Sesone	3	90% ww	3.70
15	Dacthal	3	75% wp	4.44
16	Dalapon	3	74% wp	4.50
17	Buturon	3	50% wp	6.67
18	Chlorpropham	3	40% ec	8.32
19	Diuron	3	80% wp	4.17
20	TCA	3	100% product	3.33
21	C6989	3	36% ec	9.25
22	C9122	3	50% wp	6.67
23	C10725	3	50% wp	6.67
24	MB 8882	3	75% wp	4.44
25	C3470	3	50% wp	6.67
26	R7465	3	50% wp	6.67
27	Dicamba	3	48% ec	6.94 ml
28	Monolinuron	3	50% wp	6.67
29	2725 A1	3	100% product	3.33
30	BiPC	3	100% product	3.33

Treatments are to be applied when the first pink striga flower is seen in the experiment. The larger diluent bottle should be used and 9 yard only of the plot treated.

PLOT SIZE: Gross 2 yard x 10 yard

Net 1 yard x 10 yard

For observation only, each plot is to be divided into 10 subplots each 1 yard long. The net plot consists of one furrow and two rows of sorghum. The discard interrow will not be observed.

BASAL FERTILISER:

1 cwt. of 21-14-0 compound = 227g per gross plot placed at thinning.

CROP: 'B' lines self fertile maintainer line of sorghum. Sow at 5 seeds per stand, 1 stand per yard. Supply missing stands as often as required. Thin to one plant per stand.

CULTIVATIONS: Do as little hand cultivation as possible. Use bullock drawn Unibar ripper and remoulder as required. Treat ridges and other areas not covered by the bullock cultivations with paraquat at 1 pint per acre applied with the dribble bar (see handing over notes) until time of head exsertion, then stop treating the net

plots but continue to treat the discard furrows.

OBSERVATIONS REQUIRED:

(1) Stand count at thinning on a subplot basis.

(2) Before applying treatments, count the number of emerged striga on each 1 yard subplot.

(3) After treatment, observe at weekly intervals:-

(a) Subplot with no living striga present.

(b) Subplots with emerged striga but no flowers.

(c) Subplots with striga in flower.

(4) At harvest time record:-

(a) Air dry weight of sorghum head per subplot.

(b) Air dry weight of sorghum stem per subplot.

(c) Air dry weight of sorghum grain per subplot.

(d) Air dry weight of striga which has flowered per subplot.

(e) Air dry weight of striga which has not flowered per subplot.

(5) Collect, dry and weigh mature heads in each subplot

APPENDIX 18

AM11(67)R68: Striga control granules

OBJECT: To measure the effect of granular herbicides applications on striga infesting sorghum.

SITE: S9 - New Extension.

DESIGN: 2 x 8 factorial. Simple 4 x 4 lattice (Plan 10.2 in Cochran and Cox p.428).

TREATMENTS:

Times of application	Symbol
Early pre-sowing	E
At thinning	T

X

Herbicide treatments		Product required
Nil*	-	
Atrazine 4% granules at 3#	Atg	450g/plot
Chlorthiamid 7.5% granules at 1# (Prefix)	Ch	80g/plot
Vegiben (Amiben) 10% granules at 1#	V	60g/plot
C6989 5% granules at 1#	C	120g/ "
Fenuron 25% granules (DYbar) 1#	D	24g/ "
Prometryne 4% granules 1#	P	150g/ "
Meditonerb acetate 6% granules 3#	Me	300g/ "

CROP: Sorghum Short Kaura. Thin in to 2 plants.

PLOT SIZE: Gross 8 x 8 yard = 1/75.6 acres

Net 6 x 6 yard = 1/134.4 acres.

DETAILS OF APPLICATION:

Broadcast materials on plots and incorporate with Unibar cattle toolbar.

SOWING: 4 seeds per hole + 1 pinch of striga 'seed' at 2 ft. between each stand in the row.

CULTIVATIONS: Normal inter-row cultivation with Unibar + hand-weeding as required.

FERTILISER APPLICATION: None.

OBSERVATIONS REQUIRED:

(1) Germination stand count on net plots, supply once only.

(2) At first striga flower on any plot, record the number of striga infested sorghum plants in each net plot. (Use 'striga symptons' in case of doubt).

(3) Final stand count at harvest on the net plots.

(4) Weight of unthreshed heads per net plot.

(5) Weight of threshed grain per net plot.

(6) Weight of stalks per plot.

(7) Air dry weight of striga which has flowered on each net plot at harvest.

(8) Air dry weight of striga which has <u>not</u> flowered on each net plot at harvest.

(9) Total number of striga stems per net plot. (Obs. 7 + 8)

(10) Do general weed control observations. (No weekly scoring).

(11) Do general weed score before each occasion on which the experiment is weeded.

* One set of Nil treatment may be selected for weekly hand pulling if the experiment is even enough.

Treatment	Symbol
Nil	- -
Handpulling of all emerged striga each week	H -

APPENDIX 19

DP15(68): Striga control granules

OBJECT: To measure the effect of herbicide application on striga infesting sorghum.

SITE: Choose a site which grew sorghum in the previous season which is known to be infested with striga.

DESIGN: 2 x 5 factorial. 20 plots in 2 blocks of 10 plots.

TREATMENTS:

Fertiliser treatments	Symbol
Nil	-
21-14-0 compound fertiliser applied before sowing	F

X

Herbicide treatments

Nil	-
21-14-0 compound fertiliser 3 cwt/acre broadcast at thinning	N
Atrazine 4% granules 3# broadcast at thinning	Atg
Meditonerb acetate 6% granules 3# broadcast at thinning	Me
Chlorthiamid 7½% granules 1# broadcast at thinning	Ch

CROP: Sorghum recommended local variety at 2' apart on 3' ridges.

PLOT SIZE: Gross 8 x 8 yard = 1/75.6 acres

Net 6 x 6 yard = 1/134.4 acres.

SOIL SAMPLE: Make a composite sample of soil collected from the top six inches on <u>every</u> plot of the experiment before applying any treatment.

METHOD OF APPLICATION:

<u>Fertiliser treatments</u>

Apply the fertiliser (10 bags marked F) according to the instructions for applying superphosphate in 'Recommended practices for Guineacorn production', Ministry of Agriculture RECOMMENDED PRACTICES No.2 to the 10 plots marked 'F' on the plan.

<u>Herbicide treatments</u>

Treatments N, Atg, Me and Ch (4 bags each) should be broadcast by hand on the correct plots as evenly as possible immediately after thinning the sorghum.

SOWING: Twenty bags (labelled STRIGA) of striga 'seed' are provided. A 'pinch' (about enough to cover a penny) of this material should be put into each sowing hole with the sorghum seed. Any striga seed left

over after sowing a plot should be broadcast as evenly as possible over the surface of the plot. Use of one bag of striga seed/plot.

CULTIVATIONS: Use normal hand-weeding but record any obvious treatment effects on general weed control.

OBSERVATIONS REQUIRED:

(1) Site history.

(2) Germination stand count on the net plots, supply once day.

(3) At first striga flower, record the number of striga infested sorghum plants in each net plot.

(4) Final stand count at harvest on the net plots.

(5) Weight of unthreshed heads per net plot.

(6) Weight of threshed grain per net plot.

(7) Weight of stalks per net plot.

(8) Air dry weight of sorghum which has flowered on each net plot at harvest.

(9) Air dry weight of sorghum which has not flowered on each net plot at harvest.

APPENDIX 20

The accuracy of manual broadcast applications

Investigations into the evenness of manual applications by different grades of operators were started in the dry season 1967. The planned series was terminated by the sudden death of the assistant in charge whose full experimental notes were not subsequently recovered.

Each operator broadcast 1 lb. of single superphosphate on a 1/100 acre plot. Ten petri dishes were placed at random positions in the plot to sample the distribution of the granules. Each operator also sprayed 1 gallon of water containing 0.1 lb. product of propazine on a 1/100 acre plot. The distribution was sampled by pre-weighed filter papers which were afterwards oven dried and weighed again.

With both types of application and all groups of operators, the distribution was found to be log normal. The variation between operators in a group was very small compared with the variation in one application or between groups. A proportion of observations were spoiled.

Table 20.1 shows that inexperienced temporary labourers were much less accurate than the experienced permanent labourers. The effect of experience and training in increasing the evenness of manual applications indicates that the efficiency of granular herbicides should increase progressively when farmers apply them as a routine.

Table 20.1: Variations in manual broadcast applications

All data as fractions of the intended mean.

Operator group	Numbers of Operators	Numbers of Observations	Type of application	Log mean	Upper 5% cl	Minimum safe selectivity ratio
Scientific staff	4	35	Granules	Data missing		-
" "	4	36	Spray	0.95	1.70	1.8
Permanent labourers	5	43	Granules	0.91	1.94	2.2
" "	4	29	Spray	0.97	1.63	1.6
Temporary labourers	6	55	Granules	0.72	3.51	4.9
" "	3	26	Spray	0.68	3.49	5.1

Note: The confidence limit is '1-tailed', i.e. the limit will be exceeded in 5% of the observations.

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