STUDIES ON NUT-GRASS (Cyperus rotundus L.), ESPECIALLY ITS EFFECT ON CROP YIELDS

by

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Preliminary work

(a) Reexamination of literature

The weed had been distinguished in the field from other members of the Cyperaceae, and the more obvious name agreed, a study was made of the existing literature on the weed which proved to be extensive. This is not due to the fact that the weed occurs throughout the tropics, sub-tropics and even certain temperate regions. Also, the very rapid spread of vegetation from covers makes it extremely difficult to control. References on its use were numerous; however, i.e., the suppressive effect on crop yields at the time of heavy weeds in controlling it, the varying ease.

The research into possible methods of control has been well reviewed by Asmow (1930) and Lecointe (1936). In essence, these are as follows. In regions with a severe dry season a good kill is obtainable by deep ploughing during the dry period to a depth greater than that of the great majority of the weeds. In other areas frequent cultivations aimed at removing the weeds in order to weaken the weeds have had some effect, but were required for too often to be an economical method of control. Numerous chemical weed-killers have been tried, especially 2,4-D. Most of these, including the latter, have the effect of killing the leaves and possibly the upper part of the root, but not the deeper roots. The advantage of this is that the root is killed, which makes it susceptible to cultivation and then treated with a chemical weed-killer. Although there were many weeds that were not killed by treatment, and then treated with a 2,4-D at the proper time in the season, it was often necessary to use a chemical weed-killer.
INTRODUCTION

The purpose of this work was to study the weed nut-grass (*Cyperus rotundus* L.) with a view to finding out any information which might be of use in devising a method of controlling it under the conditions of Trinidad. Two lines of approach were adopted:

1. An attempt was made to estimate the seriousness of nut-grass as a weed, due to the dearth of literature on this subject.

2. A rough trial of one of the more promising methods of control was conducted.

PRELIMINARY WORK

(a) Examination of literature

Once the weed had been distinguished in the field from other members of the Cyperaceae, and its more obvious habits noted, a study was made of the existing literature on the weed which proved to be copious. This is no doubt due to the fact that nut-grass occurs throughout the tropics, subtropics and even certain temperate regions. Also, its very rapid means of vegetative spread from tubers makes it extremely difficult to control. References to its true seriousness, however, i.e. its depressant effect on crop yields, or the time or money spent in controlling it, are very rare.

The research into possible methods of control has been well reviewed by Sparrow (1958) and Lemaistre (1958). In essence, these are as follows. In regions with a severe dry season a good kill is obtained by deep ploughing during the dry period to a depth greater than that of the great majority of the tubers. In other areas frequent cultivations aimed at removing the foliage in order to weaken the tubers have had some effect, but were needed far too often to be an economic method of control. Numerous chemical weed-killers have been tried, especially 2,4-D. Most of these, including the latter, have the effect of killing the leaves and possibly the uppermost tuber, but are not translocated to the deeper tubers, which subsequently sprout. One method in use, therefore, is to cultivate the soil, which tends to separate the tubers and cause them to sprout, and then apply 2,4-D to the shoots; this is then repeated about six weeks later. For small areas fumigation with
methyl bromide under a gas-proof cover is very effective. Recently, weed-killers have been found which, in laboratory studies using radioactive carbon, were more thoroughly translocated than 2,4-D (e.g. Amitrol); they are not yet considered an economic proposition, however. In Fiji (and probably in British Guiana) flood fallowing effectively kills nut-grass. Cover crops and leys suppress it, but the tubers remain dormant and will sprout as soon as the land is ploughed.

From a study of previous writings, especially those of Andrews (1940), it became clear that the feature of nut-grass which renders it so difficult to control is its ability to form new tubers very rapidly and to spread from these by means of rhizomes. Evidently the depth to which the tubers occur varies according to the habitat (Tothill, 1948), and it was therefore considered important to devise a quick and simple quantitative method of sampling the soil for tubers to various depths.

(b) Construction of a core-sampling device to estimate tuber numbers

After initial attempts to take samples with a spade, this method was abandoned, largely because of the variation in sample volume and the inability to prevent tubers falling from one soil layer to another. However, by shaking the samples so obtained through a ¼" mesh sieve, a very rough idea was obtained of the tuber population which might be expected in selected areas of the College grounds. With this information a core-borer was constructed having a diameter of 6" and a length of 2'6". This diameter proved to be such that light infestations could hardly be detected; on the other hand, with any larger diameter, the counting of the tubers obtained from heavily infested land would have been a major operation.

The core-borer was cut from ½" thick, 6" diameter mild steel pipe. The lower end was cut as an auger and handles were welded onto the upper end. Rings were painted around the outside at 3" intervals to show the operator the depth of penetration (Fig. 1).

Because of the difficulty of penetrating the soil, even in the wet season, and of subsequently removing the soil sample from the pipe, it was found that the only practical way to take the samples was to bore 3" at a time, removing that sample from the pipe before boring the next 3". When the soil was moist each 3" sample remained in the core-borer when it was lifted, breaking off
quite clean from the underlying soil. It could then be pushed straight out of the borer into the collecting bag by means of a stick. This way proved quite quick and efficient, taking about 15 minutes for 12" deep sample. So rarely were any tubers found in the 9-12" depth that 12" was considered to be the maximum depth to which it was worth boring. Each spot sampled, therefore, yielded four soil samples representing the soil layers 0-3", 3-6", 6-9" and 9-12". Each of these was placed in a separate polythene bag with a label and sieved through a 1/8" mesh sieve as soon as possible to extract the tubers. If it was required to know the viability of the tubers they were wrapped with their label in a piece of paper, placed in a perforated polythene bag, thoroughly soaked with water and left for five days. At the end of this period the sprouted and unsprouted tubers were counted and the percentage of sprouted ones calculated. A longer period than five days in which to sprout might have given somewhat higher viability figures, but if left too long the contents of the polythene bag would become an inseparable mass of nut-grass. This method proved quite quick for providing relative figures.

In the dry season boring below 6" proved virtually impossible. Furthermore, the soil core tended to drop out of the tube when the latter was lifted, making it necessary to collect up the fallen soil and thus probably adding to the error.

Fig. 1 The Core-Sampler.
(c) Findings made with the core-sampler

The first site chosen for tuber sampling was a Guatemala grass field showing no aerial growth of nut-grass at all. Nevertheless three borings spaced at the corners of an equilateral triangle of side 6 ft yielded the numbers of tubers shown in Table 1.

Table 1. Tuber numbers in Guatemala grass field

<table>
<thead>
<tr>
<th>Layer</th>
<th>Boring</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3&quot;</td>
<td></td>
<td>6</td>
<td>22</td>
<td>3</td>
<td>31</td>
</tr>
<tr>
<td>3-6&quot;</td>
<td></td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>6-9&quot;</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9-12&quot;</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>12-15&quot;</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>9</td>
<td>26</td>
<td>4</td>
<td>39</td>
</tr>
</tbody>
</table>

(Note: The volume of a core sample 6" diameter and 3" long is 84 cu. in. Hence division of figures for each sample by 84 gives the density per cu.in.)

A second site, once part of a cocoa plantation, and since used for burning brushwood, had a dense stand of pure nut-grass along the western side used most recently for burning and, on the other (eastern) side, a weed association in which nut-grass was only a minor contributor. Four borings, in a line about 15 ft apart, were made on each of these areas. The numbers of tubers found are given in Tables 2 and 3.

Table 2. Tuber numbers on the most recently burned (westernmost) area

<table>
<thead>
<tr>
<th>Layer</th>
<th>Boring</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3&quot;</td>
<td></td>
<td>186</td>
<td>140</td>
<td>66</td>
<td>0</td>
<td>392</td>
</tr>
<tr>
<td>3-6&quot;</td>
<td></td>
<td>80</td>
<td>146</td>
<td>16</td>
<td>9</td>
<td>251</td>
</tr>
<tr>
<td>6-9&quot;</td>
<td></td>
<td>2</td>
<td>19</td>
<td>3</td>
<td>19</td>
<td>43</td>
</tr>
<tr>
<td>9-12&quot;</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>268</td>
<td>305</td>
<td>85</td>
<td>33</td>
<td>691</td>
</tr>
</tbody>
</table>

Table 3. Tuber numbers found on the less recently burned (easternmost) area

<table>
<thead>
<tr>
<th>Layer</th>
<th>Boring</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3&quot;</td>
<td></td>
<td>3</td>
<td>10</td>
<td>0</td>
<td>114</td>
<td>127</td>
</tr>
<tr>
<td>3-6&quot;</td>
<td></td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td>6-9&quot;</td>
<td></td>
<td>0</td>
<td>6</td>
<td>1</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>9-12&quot;</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>3</td>
<td>22</td>
<td>1</td>
<td>129</td>
<td>155</td>
</tr>
</tbody>
</table>
Finally, twelve borings were made on a rectangular grid pattern on a piece of weed-covered Old Farm land next to the plots used by the Year II Diploma students, which was ploughed a month previously. The borings were made in three rows running North-South, 18 ft apart, each of four borings spaced 15 ft apart in the row. After making the borings an attempt was made to see whether there was any similarity between the distribution of nut-grass and that of other weed species. For this purpose a 40 cm. x 40 cm. quadrat was placed over each bore-hole in turn and the number of plants of each species within the quadrat was counted. The results of this quadratting and the borings are given in Table 4, page 6.

(d) Conclusions drawn from quadratting and core-sampling around L.C.T.A.

All the above data were collected in the College grounds on a soil type known as St Augustine loam, being an immature loam of variable texture formed from transported schist from the Northern range of hills and having a water table always at about 24 ft.

In such conditions it would appear that, very roughly, 60% of the tubers occur in the top 3" of soil, 30% in the 3-6" layer, 9% between 6" and 9" and 1% below this depth.

Secondly, it is clear from a comparison of tuber numbers on site one (Table 1), where there was no aerial nut-grass growth at all, with those of site three (Table 4), for which the amount of aerial growth is indicated in the table, that there is no overall correlation (i.e. applicable to any situation) between tuber numbers and top growth. If, however, the top growth and corresponding tuber numbers are compared within in single uniformly-treated site, such as site three, a very clear correlation is found (r = .916 for the correlation between total tuber numbers and aerial plant numbers of nut-grass in Table 4).

Significant positive correlations were also found between the numbers of nut-grass plants at the various sampling points on site three and the corresponding numbers of Euphorbia geniculata (r = .695), Cynodon dactylon (r = .594) and Cleome rutidosperma (r = .802). This appeared to be partly due to the fact that each of these species was unable to establish where there were patches of tall Bird seed grass (Panicum fasciculatum) (r = -.424, not significant).
Table 4. Tuber numbers and numbers of individual plants of each associated species on site three

<table>
<thead>
<tr>
<th>Position</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-3&quot;</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>27</td>
<td>0</td>
<td>2</td>
<td>16</td>
<td>1</td>
<td>0</td>
<td>9</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>3-6&quot;</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>21</td>
<td>0</td>
<td>1</td>
<td>15</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>6-9&quot;</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>31</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9-12&quot;</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>79</td>
<td>0</td>
<td>3</td>
<td>37</td>
<td>1</td>
<td>0</td>
<td>14</td>
<td>31</td>
<td></td>
</tr>
</tbody>
</table>

Species

- **Cyperus rotundus**: 18 0 1 55 0 1 10 37 1 0 7 49
- **Amaranthus sp.**: 4 1 6 17 8 11 4 16 10 11 10 9
- **Cleome rutidosperma**: 1 0 3 20 1 0 5 11 2 0 1 4
- **Cynodon dactylon**: 9 0 0 1 3 0 6 10 5 2 0 20
- **Eclipta alba**: 1 0 5 0 0 1 2 0 0 0 4 0
- **Eleusine indica**: 7 0 4 3 0 4 8 4 3 2 3 2
- **Euphorbia geniculata**: 0 1 0 3 0 0 1 3 0 0 2 15
- **Euphorbia hirta**: 0 0 0 0 0 0 3 1 0 0 0 0
- **Leptochloa scabra**: 2 0 24 0 0 3 2 0 5 18 10 0
- **Panicum fasciculatum**: 0 19 0 0 0 10 0 0 1 12 0 0
- **Paspalum fasciculatum**: 10 0 0 0 2 0 2 2 1 0 2 0
- **Portulaca oleracea**: 5 0 2 8 8 1 0 7 4 1 0 0
- **Phyllanthus amarus**: 0 2 3 2 0 2 2 1 0 2 1 1

(Note: The actual area of this quadrat was 40 cm. x 40 cm. minus the area of the core sample hole, i.e. 16$^2$ - 3$^2$ or 229 sq.in. Most of the weeds were very young and had not yet flowered. The ground cover was therefore not complete although the weed stand appeared to have closed up its canopy.)

Two tentative conclusions may be drawn from these results: firstly, that certain cropping systems (such as Guatemala grass cut for forage) may suppress top-growth of nut-grass without killing the tubers; and secondly, that the patchy distribution of the nut-grass is not solely due to its vegetative means of spread, but is influenced by other factors which also affect the distribution of seed-dispersed species such as *Cleome rutidosperma*.

(e) Local practice in the control of nut-grass

Before any experiments were planned a number of small-holders in the vicinity of I.C.T.A. were consulted in order to find out how seriously nut-grass is regarded and the measures taken to control it.

Its frequency appears to be greatest on vegetable plots and it is not
regarded as a serious weed on the cane fields by Messrs Caroni Limited.

Several people considered that it is not a bad weed and yet it appeared that considerable time is spent in attempting to control it. For tall crops, such as corn, one to three hoeings during the early life of the crop are all that are considered justifiable whereas in very low-growing crops, like lettuce, it is regarded as a great danger and it is not unusual for women to try to fork out all the tubers in their lettuce beds, although they realise the impossibility of removing every one.

It was universally held that there was no way of eradicating nut-grass and that even if the land were cultivated in the dry season the weed would reappear immediately the rains began. It has since become apparent that there is every reason for this belief.

INTERIM CONCLUSIONS - BASIS FOR THE CHOICE OF EXPERIMENTS

During the course of the preliminary work described above, it became clear that not only is a form of control applicable to Trinidad needed but that, equally necessary, is an estimate of the yield depression caused by nut-grass in various crops, so that the economic justification for both present and future control measures may be calculated. Its vegetative spread by means of rhizomes is very rapid, and it possesses the ability to recover very quickly from setbacks such as cultivation, due to the tuber food reserves. Added to these features, there is a tendency for previously dormant tubers to shoot whenever they are separated from one another, due to removal of apical dominance (Smith and Fick, 1937). Together, these characteristics mean that any form of control which is incomplete is likely to have to be repeated often and thus cost a considerable amount in labour.

The cheapest and most effective means of control described in the literature consists of deep ploughing in the dry season. This, however, is used in a region with a severe dry season, i.e. the Sudan, and it remained to be seen whether in Trinidad the main dry season, from January till late May, would be harsh enough to apply this technique successfully. The principles of this method and a rough trial of it are described in a later section.

Meanwhile, an experiment was begun to evaluate the loss in yield caused by nut-grass to two crops.
EXPERIMENT TO FIND THE LOSS IN CROP YIELD CAUSED BY NUT-GRASS

(a) Findings of previous workers

Despite an abundance of literature on the subject of nut-grass and its control, there are very few references to its effect on crop yields. Ranade and Burns (1925) quote from a letter written in 1920 by the Director of Agriculture of the Bombay Presidency, to the effect that nut-grass probably reduced yields on fertile lands by 25-30%; no evidence is mentioned, however. Toms (1957), describing how nut-grass is controlled in the Sudan Gezira, states that the measures used, which also control Cynodon dactylon, result in a yield increase of .5 kantars per feddan of seed cotton, or about 160 lb per acre—worth £5.

(b) Object

The object of this experiment, therefore, was to find the effect of different degrees of infestation of nut-grass on, firstly, a fairly tall, smothering type of crop and, secondly, a lower growing and presumably more sensitive crop. The information so obtained could then be used in planning nut-grass control from an economic standpoint.

(c) Planning the experiment

(i) Obtaining the different nut-grass infestations

The first problem encountered was that of obtaining different levels of nut-grass infestation arranged in experimental plots. The early tuber studies had shown that it would be quite impossible to plant out tubers on to plots in sufficient numbers to simulate a natural infestation and there was not time available to plant out small numbers in the hope of their multiplying up to the desired level. Furthermore, even if time had been available to use this method, it is possible that, by the time the required amount of multiplication had occurred, the tuber numbers would no longer be in the proportions required on the various plots. It was therefore decided to perform the experiment on an already infested piece of land, and to vary the nut-grass infestation by removing the top-growth of the weed at varying intervals. Hoeing was not considered a suitable method of removing the top-growth since this would have had the secondary effect of breaking up the surface soil pan...
which, as it transpired, might have been considerable. The method chosen was to clip off the nut-grass shoots with scissors at ground level at weekly, fortnightly and three-weekly intervals, and not at all. Although laborious, this method had the advantage that all the nut-grass produced on each plot could be collected and weighed, so that the treatment under which the greatest bulk of nut-grass was produced could be identified. To avoid confusing the effect of nut-grass with that of other weeds the latter would obviously have to be removed very frequently.

(ii) Choice of test crops

Two short-term test crops were needed which could be planted in December and harvested within three months. They had preferably to be crops popular with local vegetable growers and must be capable of cultivation in small pots, since it is rarely possible to find a large area evenly infested with nut-grass. Lettuce (Lactuca sativa) was the obvious choice for the low-growing crop, especially as it is one of the most profitable market-garden crops at present. For the taller, more smothering crop, a new dwarf variety of cowpea from Suriname (Vigna sinensis var. Capucijner) was chosen. These two crops were not combined in the same experiment since the measurements taken on them would not have been comparable quantities. They were therefore grown in separate but adjacent areas.

(iii) Fertiliser treatments

The purpose of introducing fertiliser treatments into the experiment was not to assess the response of the crops to fertiliser. Half of the plots were fertilised and half were not in the expectation that, if the effect of nut-grass were due to competition for nutrients, this effect would be least on plots with an ample supply of them.

(iv) Experimental design

A similar design was chosen for both the lettuce and the cowpea experiment, namely a $4 \times 2$ factorial layout with three replications. The main plots representing the two treatments, "fertilised" and "not fertilised", were each split into four subplots representing the four different levels of nut-grass infestation. The reason for using this split-plot design, instead of an ordinary randomised block design, was to ensure the most precise possible comparison between the effects of the levels of nut-grass infestation
and their interactions with the fertiliser treatment. Direct effects of fertiliser were of no importance and the likelihood of being able to measure these was sacrificed in order to be able to place each group of four "nut-grass-infestation" treatments close together, and thus most probably on a uniformly infested piece of land. The final layout after randomisation is shown in Fig. 2.

Let us consider the layout of the experiment to assess the effect of nut-grass on crops.

Note:

N1 indicates subplots on which nut-grass was clipped weekly.
N2 " " " " " " fortnightly.
N3 " " " " unclipped until the end of the experiment.
O " fertilised plots.
F " unfertilised plots.

(v) Size and shape of plots

The minimum number of lettuces suitable for a subplot was considered to be thirty, since with any smaller number than this the loss of a single lettuce would represent a substantial proportion of the subplot yield. The subplots had to be narrow enough to be hand- weeded from the side whereas the whole plots, over which it was important to have an even stand of nut-grass, would be most likely to approach this ideal if square. In fact the main plots were 4 yds x 3 yds, divided into four subplot strips of 3 yds x 1 yd. Each of these was to be raised into a bed 2 ft wide leaving a 1-ft gap between beds. Such beds were to carry three rows of 10 lettuces or three rows of 5 cowpea plants.
(vi) **Choice of site**

A strip of land between the Botany department and the railway had been cleared from banana cultivation about a month previously and part of this had been rotary-hoed. On this part there was a dense stand of nut-grass in the flowering stage, and the area was chosen as being sufficiently evenly and heavily infested for the experiment.

(vii) **Soil and climate**

The soil may be briefly described as a sandy clay loam of the St Augustine series, and the climate as wet tropical with a pronounced dry season. For further details, see Appendix 1.

(d) **Procedure**

(i) **Preparation of site**

On December 12th, 1959, after removal of a remaining banana tree, the area which had been previously rotary-hoed was rotary-hoed once more, to a depth of about 6", the maximum to which the machine would penetrate in the sticky soil. A second strip, not previously disturbed, but lying along the eastern edge of the first, was treated in the same way, but later proved to have a very much smaller population of nut-grass. This second strip was used for the cowpeas while the first was used for the lettuces.

(ii) **Preparation of plots**

Local practice in vegetable growing is to plant on raised beds, about 4" high and 1 ft to 3-4½ ft wide, in order to facilitate drainage and hand operations on the crop. Such beds were used in this experiment for subplots, each one being 2 ft wide, 4 in. high, and 9 ft long. They were spaced apart at 3 ft centres, and each of the three blocks of eight subplots were separated by a gap the size of one subplot.

After another rotary-hoeing on December 14th, which, due to the drier conditions, left the soil in much better tilth than before, these plots were marked out and set up.

(iii) **Application of fertiliser**

A mixed fertiliser was applied by hand to the appropriate plots intended for lettuces on December 16th, and to the appropriate ones intended for cowpeas on the following day. The amount used per subplot was the same for
both crops, i.e. 5½ ozs of a mixture containing 3 parts by weight of ammonium sulphate, 1 of potassium chloride, and 1 of superphosphate: equivalent to 500 lbs, 150 lbs and 150 lbs per acre respectively.

(iv) Initial tuber sampling

Before either crop was planted, core-samples of soil were taken, in the same way as described in section II, at four points on each experimental area marked a, b, c, and d on the lettuce area, and e, f, g and h on the cowpea area in Fig. 2.

(v) Planting and spraying

The cowpea seeds were sown on December 17th, two per hole (thinned to one after germination). The majority braided between four and seven days later, and two days after planting the equivalent of 70 gallons per acre of 1:200 Dieldrex was applied to control mole-crickets (Scapteriscus vicinus).

Lettuces for transplanting were obtained from San Antonio Nursery, Santa Cruz, and had been grown on rather heavy clay beds out of doors. They were also smaller than is normally considered ideal, and it was possibly due to these two factors that very frequent supplying proved later to be necessary. After thorough irrigation of the beds (December 18th) and spraying with Dieldrex as on the cowpea plots, the lettuces were planted out between 2.45 and 4.30 p.m. They were in the 3-5 leaf stage, about ½-1" across. On the morning after planting the majority had recovered their turgidity.

(vi) Watering

After planting, the lettuces were watered with a hose every morning and evening (except when rain fell) until they were nearly mature. Within three days they began to die, and although the cause of death was not at the time attributed to damping-off (Rhizoctonia solani), it seems probable that the deaths were partly due to the watering regime. The combination of rose and water pressure used tended to stick the outermost lettuce leaves to the soil, and panning of the surface was unavoidable. This pan was broken up around each lettuce plant with a small stick, three times during the growing period, but no thorough soil stirring could be applied for fear of disturbing the nut-grass. With this watering regime, it was only the top ½" crust which ever dried out.

The cowpeas were also watered when it was considered necessary, i.e. about once a week.
Lettuce losses. Shading and supplying.

The most serious factor detracting from the value of this experiment was undoubtedly the necessity to replace large numbers of lettuces, even as late as January 12th. Eventually, rather more lettuces were supplied than had been planted initially. The affected plants first turned brown at the leaf edges, and then turned black and soft all over, after which they shrivelled up. Although not considered so at the time, it is possible that this was in fact due to *Rhizoctonia solani*, and could have been controlled by spraying.

Supplies were planted on December 23rd (about 10%), December 31st (about 60%), January 7th (Blocks I and II) (about 40%) and January 12th (Block III) (about 40%). The last lot of supplies used on Block III had been grown by San Antonio Nursery in boxes with some compost, since they had been experiencing the same difficulty, and these grew much better than all previous planting material. Despite all this supplying, a count made on January 30th showed an average number of surviving lettuces of 21 instead of 30 per plot, and the average number finally harvested per plot was 18.

Between December 31st and January 15th the lettuce plots were shaded with coconut fronds, in the hope of cutting down these losses.

Even the surviving lettuces on the fertilised plots did not thrive as they should have done.

Had the number of lettuces dying on each plot borne any relationship to the treatment being applied to that plot, it would obviously have been wrong to make good these losses, especially with material which might differ from that used previously. However, this did not appear to be the case, and the procedure of supplying was adopted, *faute de mieux*. It certainly added to the error, but it is assumed that it did not bias the results.

Clipping and collection of nut-grass

At the time when the lettuces were planted, nut-grass was already beginning to sprout evenly all over the lettuce plots. On the cowpea plots, there proved to be a very much smaller nut-grass population, and it was only on the unclipped cowpea plots that a moderately serious nut-grass infestation developed. Due to this, the results of the two experiments are not comparable.

Clipping of the "weekly-clipped" lettuce subplots was first done a week
after planting, and every week thereafter. On this first occasion the nut-grass was not collected; and the cowpea plots were not clipped, in order to give the nut-grass a better chance to establish. Every subsequent week until the crops were harvested, however, all the "weekly-cut" and the appropriate "fortnightly-cut" and "three-weekly-cut" subplots on both experimental areas were clipped, and the nut-grass collected, dried and weighed. For this purpose a wooden frame 9 ft x 2 ft was made, to demarcate a standard area from which to collect the foliage. Three or four men were required every week for this job, which took them most of the day. After being clipped, the nut-grass was washed and spread out to dry for about a day before being finally dried off for 24 hours in the oven at 95°C, after which it was allowed to cool in a desiccator and weighed. The clippings collected on December 31st were also subjected to analysis for nitrogen content.

No. 1 lettuce plot was cut by mistake on January 8th and had to be treated as a missing plot in all the calculations, although its normal clipping regime was continued.

(ix) Further sprayings

The death of a few of the cowpea plants was thought to be due to the mole-cricket, and a second spraying of 1:200 Dielddrex at the same rate as the first was applied to both the lettuces and the cowpeas on January 8th. On February 5th, partly to control a caterpillar which was eating the cowpeas, but mainly to prevent theft, both crops were dusted with Agroicide and a notice was put up to the effect that they had been dusted with poison.

(x) Regular weedings

For the first fortnight after planting the crops, nut-grass was the only weed present, but after that, other weeds, notably Phyllanthus amarus and P. urinaria, Euphorbia hirta and E. hypericifolia, Eleusine indica and other grasses appeared in increasing numbers, and all these were hand-pulled every week. Late in the course of the experiment, there was a tendency for this to be neglected under the dense cowpea cover and on the "uncut" lettuce plots, but this is not considered to be a very serious defect since the weeds left were only small seedlings. On the uncut lettuce plots there was a very heavy stand of sedge, some of which, on flowering, turned out not to be nut-grass. Such seedling sedges did not occur on the clipped plots, possibly because the
soil of these became more panned and baked than that of the unclipped plots.

(xi) Progress of the crops and the nut-grass

The slow growth of the lettuces has already been mentioned. It may be added that those growing in the dense stand of uncut nut-grass did not appear to suffer greatly, and were, in fact, much cleaner and damper than those on the clipped plots, since they were shaded by the nut-grass which also prevented the soil from splashing up during watering. The shading effect also appeared to inhibit the development of the purple colour which is characteristic of the variety of lettuce used, but this was not checked objectively.

The cowpeas made excellent growth throughout the course of the experiment; in fact it was unfortunate that they were not grown on the lettuce area with the heavier stand of nut-grass, since they were definitely the better test crop. On January 29th many were in bud, and by February 8th flowering had begun. It was very noticeable by then that the fertilised plots bore bigger plants, with more flowers, than the unfertilised ones (the canopy of the former now being completely closed). The fertilised plants completed flowering and died down after cropping about a week earlier than the unfertilised.

The nut-grass, in its recovery from clipping, responded very clearly to the different frequencies of clipping; the stand on the weekly-cut plots becoming successively weaker until, towards the end of the experiment, there was not always sufficient to clip (see Table 8 and Fig. 3). This was despite regular irrigation. The nut-grass cut every third week did not appear to weaken at all, and that cut every second week was intermediate. Only the uncut nut-grass flowered, and this process reached its peak on about January 12th, after which much of the foliage died and rotted. Possibly due to the lack of irrigation, none of the cowpea plots carried enough nut-grass to be worth clipping after February 12th; even that which was uncut having completely died down by the time the cowpeas were harvested.

(xii) Harvesting

The lettuces varied greatly in size, and were therefore harvested on three separate dates, February 16th and 26th and March 11th, during the afternoons. Those which were considered large enough on each occasion (except the last, when all that remained were cut) were cut at ground level, counted, and weighed soon after cutting.
Unexpected difficulties were encountered in obtaining dry-matter estimates, and therefore in expressing results on a dry-matter basis. The lettuces were fairly dirty on cutting due to splash from the hose, and after the first weighing they were washed, shaken as thoroughly and as consistently as possible, re-weighed wet, and then each plot's produce was sampled for dry-matter determination. After drying, however, the samples were found to have varied so much in their dry-matter content that they were quite unreliable as a guide to the clean dry weight of the individual plot yields. On the basis that a mean is more reliable than a single reading, the results of this sampling were pooled for each of the three harvests. The figure finally used to represent a particular plot yield on a particular one of the harvesting days was thus the product of the fresh weight as cut (i.e. dirty), and a standard dry-matter content figure which was the same for every plot. The actual figures used for dry-matter content were 6.22% on February 16th, 8.39% on February 26th and 10.67% on March 11th. In future experiments, it would probably be better to avoid sampling for dry-matter, and to dry the entire produce of each plot.

The quality of the lettuces harvested on the first two dates was tolerable, but the ones cut on February 11th were quite useless, being bitter, and many of them still small, although showing signs of being about to flower.

The cowpeas were also harvested on three separate dates (February 27th, March 4th and 12th) as they reached the hard, brittle stage. They were then weighed in the pod, shelled, and re-weighed. Dry-matter content estimates for individual plots are not available since one batch of samples were scorched in the oven, due to alteration of the temperature setting during the author's absence. The dry-matter percentages obtained for each harvesting day (87.6±.5% on February 27th; 86.6±.5% on March 4th; and 85.7±.5% on March 12th) by sampling the bulked yields of all plots on each occasion were considered sufficiently similar to justify doing all computations on the fresh weights. This was in fact done although the data presented here have been multiplied by .87 to convert them to a dry weight basis.

The remaining nut-grass on all the lettuce plots was finally cut on March 11th, including that on the previously uncut plots. Immediately afterwards borings were taken with the core-sampler in the middle of each plot to a depth of 6" which was as far as the borer could penetrate.
The tubers were sieved out in the usual way through a 1/8" mesh sieve. They were then put to a viability test as described earlier.

(e) Results

It has already been explained that the experiment on lettuces and that on cowpeas were quite distinct, although lying alongside one another and being identical in size and design. Both must be regarded as being somewhat unsatisfactory, the former because of the poor growth and the necessity to supply, and the latter because of the light infestation of nut-grass. However, the design chosen, and the evenness of both nut-grass infestations, together presumably with the selection of a site with very little fertility variation, enabled several conclusions to be drawn.

Both crops were harvested on three separate dates, and in computing the results various attempts were made to combine the total yield of each plot with its mean period of growth (i.e. the sum of the products of each yield increment and the appropriate number of days since planting, divided by the total yield). It was finally decided, however, that these two measurements should be analysed and presented separately, as they are below.

The results may now be considered.

(i) The effects of the different nut-grass infestations on plot yields

These are shown in Table 5 and Fig. 3A for the lettuces, and Table 6 and Fig. 3B for the cowpeas. In these and subsequent similar tables, the four levels of nut-grass infestation are designated N1, N2, N3 and N4 as in Fig. 2.

Table 5. Lettuces: Mean yields for each treatment (pounds dry matter per acre).

<table>
<thead>
<tr>
<th></th>
<th>N1</th>
<th>N2</th>
<th>N3</th>
<th>N4</th>
<th>Mean</th>
<th>S.E. of Mean (2 d.f.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfertilised</td>
<td>256.7</td>
<td>237.4</td>
<td>229.0</td>
<td>168.0</td>
<td>222.8</td>
<td>11.1</td>
</tr>
<tr>
<td>Fertilised</td>
<td>186.0</td>
<td>185.4</td>
<td>174.5</td>
<td>117.0</td>
<td>165.7</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>221.4</td>
<td>211.4</td>
<td>201.7</td>
<td>142.5</td>
<td>194.2</td>
<td></td>
</tr>
</tbody>
</table>

S.E. of Mean (11 d.f.) 15.9
S.E. of Mean (11 d.f.) for body of table = 22.5
FIG 3A  LETTUCE:--  EFFECT OF NUT-GRASS ON YIELD

UNFERTILISED
FERTILISED
WEEKLY
THREE-WEEKLY
NOT CLIPPED
NUT-GRASS CLIPPING
FORTNIGHTLY
INTERVAL BETWEEN

LBS DM/ACRE

0

200

300

0

100

WEEKLY
FORTNIGHTLY
THREE-WEEKLY
NOT CLIPPED
NUT-GRASS CLIPPING

UNFERTILISED
FERTILISED
FIG 3B  COWPEAS: EFFECT OF NUTGRASS ON YIELD

FERTILISED

UNFERTILISED

LBS DM/acre

WEEKLY  FORTNIGHTLY  THREE WEEKLY  NOT CLIPPED

INTERVAL BETWEEN NUTGRASS CLIPPING
Table 6. Cowpeas: Mean yields for each treatment (pounds dry shelled peas per acre).

<table>
<thead>
<tr>
<th></th>
<th>N1</th>
<th>N2</th>
<th>N3</th>
<th>N4</th>
<th>Mean</th>
<th>S.E. of Mean (2 d.f.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfertilised</td>
<td>1198</td>
<td>1080</td>
<td>898</td>
<td>1010</td>
<td>1046</td>
<td>41.5</td>
</tr>
<tr>
<td>Fertilised</td>
<td>1470</td>
<td>1395</td>
<td>1418</td>
<td>1360</td>
<td>1411</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>1334</td>
<td>1238</td>
<td>1158</td>
<td>1183</td>
<td>1229</td>
<td></td>
</tr>
</tbody>
</table>

S.E. of Mean (12 d.f.) = 57.7
S.E. of Mean (12 d.f.) for body of table = 81.6

On the lettuce plots, only the very heavy infestation of undisturbed nut-grass caused any significant loss of yield, this loss being in the order of 35% compared with the highest-yielding plots on which the nut-grass was clipped every week. This loss occurred whether the plots were fertilised or not. A curious feature here is a consistent but not quite significant negative response to fertiliser.

Nut-grass only depressed the cowpea yields on the unfertilised plots, the yields of all the fertilised plots being indistinguishable. The depression, which is most marked on the plots cut every three weeks, (whose yield was 25% less than that of the weekly-cut plots) is thus probably due to competition for nutrients.

The general level of cowpea yields was increased 35% by the application of fertiliser.

(ii) The effects of the different nut-grass populations on the time taken for the crops to reach maturity

The mean number of days, D, to maturity for each crop was taken to be

\[
d = \frac{d_1 w_1 + d_2 w_2 + d_3 w_3}{W}
\]

where \(d_1\), \(d_2\) and \(d_3\) are the number of days from the first planting to the three harvesting dates 1, 2 and 3; and \(w_1\), \(w_2\) and \(w_3\) are the weight of crop obtained on each of those three occasions. \(W\) is the total weight obtained, i.e. \(w_1 + w_2 + w_3\). This value \(D\) was found for each plot on each experiment.

The result was that no differences at all in time to maturity could be found on the lettuce plots, the mean value being 78 days. This is not surprising since in practice they were not all planted on the initial planting date assumed in the above calculation, but at various dates right up till January 12th, supposedly at random.

The error on the cowpea experiment was such that one day's difference
between subplot treatments (i.e. nut-grass levels) in mean time to maturity was detectable. As with the yield data, it is only the cowpeas on the three-weekly cut plots which have been influenced by the nut-grass, the unfertilised plots having been delayed in reaching maturity by about three days, compared with their fertilised counterparts. Certain other subplot comparisons border on significance, but are not readily explainable. This is shown in Table 7.

<table>
<thead>
<tr>
<th></th>
<th>N1</th>
<th>N2</th>
<th>N3</th>
<th>N4</th>
<th>Mean</th>
<th>S.E. of Mean (2 d.f.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfertilised</td>
<td>78.0</td>
<td>77.1</td>
<td>79.1</td>
<td>78.0</td>
<td>78.1</td>
<td>0.41</td>
</tr>
<tr>
<td>Fertilised</td>
<td>76.9</td>
<td>76.5</td>
<td>75.8</td>
<td>75.8</td>
<td>76.3</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>77.5</td>
<td>76.8</td>
<td>77.4</td>
<td>76.9</td>
<td>77.2</td>
<td></td>
</tr>
</tbody>
</table>

S.E. of Mean (12 d.f.) 0.24
S.E. of Mean (12 d.f.) for body of table = 0.34

(iii) Other findings

Apart from the main findings of the experiments, described above, various other incidental findings are of interest. These are concerned largely with the effect of the different cutting regimes on the nut-grass itself. They are based mainly on the lettuce experiment, since the quantities of nut-grass cut from the cowpea experiment were smaller and more variable than those on the lettuce experiment.

Perhaps the most important of these extra data are shown in Table 8, which shows the weight of the nut-grass removed from the various plots during the course of the experiment (see also Figs. 4A, B and C).

<table>
<thead>
<tr>
<th>Date of cutting</th>
<th>Unfertilised</th>
<th>Fertilised</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N1</td>
<td>N2</td>
</tr>
<tr>
<td>24/12</td>
<td>?</td>
<td>-</td>
</tr>
<tr>
<td>31/12</td>
<td>44.5</td>
<td>71.8</td>
</tr>
<tr>
<td>8/1</td>
<td>49.4</td>
<td>-</td>
</tr>
<tr>
<td>15/1</td>
<td>35.5</td>
<td>137.4</td>
</tr>
<tr>
<td>22/1</td>
<td>25.3</td>
<td>-</td>
</tr>
<tr>
<td>29/1</td>
<td>16.8</td>
<td>76.9</td>
</tr>
<tr>
<td>5/2</td>
<td>12.5</td>
<td>-</td>
</tr>
<tr>
<td>12/2</td>
<td>5.2</td>
<td>39.6</td>
</tr>
<tr>
<td>19/2</td>
<td>None</td>
<td>93.0</td>
</tr>
<tr>
<td>26/2</td>
<td>13.3</td>
<td>27.7</td>
</tr>
<tr>
<td>4/3</td>
<td>None</td>
<td>-</td>
</tr>
<tr>
<td>11/3</td>
<td>4.7</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Total 207.2 357.9 520.7 119.0 259.9 507.5 708.0 141.0

Note: The final rotary hoeing prior to planting was done on December 14th. Clippings taken on 24/12 were not collected.

(To convert to pounds DM/acre multiply by 1.8)
FIG 4A EFFECT OF CLIPPING NUTGRASS AT WEEKLY INTERVALS

- FERTILISED

- UNFERTILISED

YIELD GMS DM/54 SQ.FT.

FOLIAGE

TUBERS

1959 DATE 1960

ROTARY HOED 2412 3H2 81 151 221 291 52 122 192 262 43 113

NUMBER OF TUBERS IN 6" DIAM DEEP CORE
FIG 4C - EFFECT OF CLIPPING NUTGRASS AT 3-WEEKLY INTERVALS

- FERTILISED
- UNFERTILISED

YIELD GMS DM
2.50
2.00
1.00
0.50
0.00

NUMBER OF TUBERS IN 6" DIAM 6" DEEP CORE
80
70
60
50
40
30
20
10
0

TUBERS
FOLIAGE

ROUGHT HOED 1959 DATE 1960
Before considering this table, it is instructive to note also the numbers of tubers found on the plots after the final crop harvest on March 11th. For comparison the initial estimate of tuber population for the same depth (0-6") is also given (Table 9).

<table>
<thead>
<tr>
<th></th>
<th>N1</th>
<th>N2</th>
<th>N3</th>
<th>N4</th>
<th>Mean</th>
<th>S.E. of Mean (2 d.f.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfertilised</td>
<td>10</td>
<td>27</td>
<td>29</td>
<td>41</td>
<td>41</td>
<td>27</td>
</tr>
<tr>
<td>Fertilised</td>
<td>12</td>
<td>42</td>
<td>58</td>
<td>61</td>
<td>44</td>
<td>3.1</td>
</tr>
<tr>
<td>Mean</td>
<td>11</td>
<td>35</td>
<td>44</td>
<td>51</td>
<td>44</td>
<td>3.1</td>
</tr>
</tbody>
</table>

S.E. of Mean (12 d.f.) 3.3
S.E. of Mean (12 d.f.) for body of table = 3.7
Estimate of number present initially, on Dec. 18th, = 16 tubers.

At the same time the viability of the tubers thus obtained is of interest (Table 10).

<table>
<thead>
<tr>
<th></th>
<th>N1</th>
<th>N2</th>
<th>N3</th>
<th>N4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unfertilised</td>
<td>51.2</td>
<td>81.0</td>
<td>79.9</td>
<td>75.8</td>
</tr>
<tr>
<td>Fertilised</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The viability of the tubers obtained on December 18th was not satisfactorily estimated.

From a study of Tables 8, 9 and 10 it is possible to draw the following conclusions.

All the clipping regimes appear to weaken the density of infestation (Table 8 and Figs. 4A, B and C). This is indicated by the steady decline in the weight of clippings obtained from all the plots. Examination of the tuber numbers shown in Table 9 and Figs. 4A, B and C, however, proves that on all but the weekly-cut plots these were increasing at a considerable rate. In fact, during the twelve weeks since the initial tuber sampling, the tuber numbers on the fortnightly cut plots doubled; those on the three-weekly cut plots multiplied two and a half times, and those on the uncut plots, three times. These figures are the means of fertilised and unfertilised plots: the actual rate of increase was much faster under the higher fertility conditions than under the lower.
In addition to preventing the increase in tuber numbers, weekly clipping caused a substantially (significant at .1% level, percentages converted by angular transformation) lower viability of the tubers, compared with those on the other plots, i.e. around 50% as against 80%. Unfortunately no satisfactory estimate was made of the initial viability, although it is most likely that this would have been in the region of 80% also; in other words, the normal viability level of about 80% was reduced to 50% by weekly clipping. This reduction in viability was not, however, accompanied by any significant reduction in numbers.

Recovery from clipping was quickest on the three-weekly clipped plots and slowest on the weekly-cut ones, especially towards the end of the experiment. This was very clear to the observer after the clippings of January 29th and March 11th, which were the only two dates on which clipping of weekly, fortnightly and three-weekly-cut plots coincided. It may also be deduced from the fact that the relative proportion of nut-grass produced on the weekly and three-weekly plots was about 1:10 at the end of the experiment compared with about 1:5 at the beginning.

The curve of the weights of nut-grass obtained from the plots cut every week for twelve weeks (Fig.4A) is clearly asymptotic, and it is likely that similar curves for less frequently cut plots would be the same if the experiment had been continued. The implications of this will be mentioned in the discussion.

The totals in Table 8 show that widening the cutting intervals will, up to a certain limit, substantially increase the weight of herbage produced. This is analogous with the findings of Woodman, Blunt and Stewart (1926) for pasture grass.

The crude protein contents of the weekly and fortnightly cut nut-grass obtained on December 31st, as found by the Kjeldahl method, were 20.66% and 18.91% of the dry weight respectively; but with only one sample from each of the twelve plots, this difference was not significant.

(f) Discussion and conclusions

For reasons given below, the chief aim of the experiment, namely to find the influence of the weed upon the crops, was not satisfactorily achieved. The findings concerning the effect of different cutting intervals upon the
weeds of the same family and are much more reliable and are discussed separately.

(i) Effect of the weed upon the crop

It has already been mentioned that the cause for doubting the applicability of the results given for yield depressions and delay of maturity (despite their significance at the 5% probability level) is quite different for the two crops. In the case of the lettuces, it is due to the very poor yields and the necessity to supply so many new plants. The cowpeas, on the other hand, gave excellent yields and proved an admirable test crop, but were planted on an area with too small an infestation of nut-grass.

It is not proposed to discuss the reasons for the poor growth and survival of the lettuces, some of which have been suggested in the text. It is likely, however, that if whatever factor was limiting growth had not been present, the influence of the nut-grass would have been even more pronounced. The maximum yield depression found (35%) is not really surprising in view of the density of the nut-grass infestation: an idea of this density is given by the fact that, during the twelve weeks of the experiment, the lettuce plots produced at least twice as much nut-grass (in terms of dry matter) as lettuce. Further doubt is cast upon the validity of the lettuce experiment by the anomalous overall negative response to fertiliser.

The result of the cowpea experiment fits in very much better with expectations, and it is fairly safe to suppose that the 25% loss of yield due to nut-grass on unfertilised plots is a real figure. Probably, therefore, a much greater loss could be expected under a serious infestation. The reason why the unclipped nut-grass, supposedly the most competitive, was not so in practice, is discussed below.

The question arises whether the technique used for producing a series of different levels of nut-grass infestation, i.e. by clipping at different intervals, had the desired effect. There are three clear objections. First, the regular clipping causes a decline in the aerial growth of the weed, which in a natural undisturbed population would almost certainly be increasing. Secondly, if the relative severity of the regimes is to be known, the nut-grass removed at each clipping should be estimated and analysed for the major nutrient elements. Finally, the absence of normal hoeing leads to a serious surface pan, with this particular soil, and although this pan was broken with a small
stick on two occasions, it returned immediately on watering. A method of watering which does not cause paning, such as an automatic sprinkler with a very fine spray, would have been better than hand-watering with the hose.

If this method of adjusting infestations is used, however, the range of clipping intervals chosen is important: in these experiments it was not correct. It was hoped that the weekly clipping regime would represent virtually a control, with scarcely any nut-grass. This was not so, and it is recommended that on a heavily infested area* (which is another necessity) the most frequent clipping should be twice-weekly. Ideally the crop should not then be planted until a few weeks after the first clipping; by that time there should be barely any nut-grass foliage on such plots. At the other end of the scale, it was found that, at the age of about four weeks, nut-grass flowers: after flowering the leaves die back and rot, and there is very little new growth. It may be, therefore, that on flowering, nut-grass is no longer a very serious competitor for nutrients, although it may then begin to have a slightly greater shading effect, caused by the remaining inflorescence. The somewhat higher yield of cowpeas on unclipped than on three-weekly clipped plots may be due to this. It is suggested, then, that the widest cutting interval should be four weeks.

A final criticism is that it was impossible to compare the results for the two crops, due to the differences in level of infestation on their respective areas. The two crops were put into separate experiments owing to the impossibility of handling the two sets of crop data together. However, if the blocks of both experiments had been treated as if belonging to the same experiment, and placed at random over the whole area, there would have been a greater likelihood of getting an average infestation of similar magnitude on both crops. As it was, an estimate of the difference in density of infestation between the two crop areas is given by the fact that the total dry nut-grass removed from the lettuce plots was 2821.2 gms, equivalent to about 622 lbs per acre, whilst that removed from the cowpea plots was only 279.7 gms, or about 61 lbs per acre; i.e. about one tenth as much.

*Assuming that a piece of land has been rotary-hoed a month previously, and that wet conditions prevail, it is reasonable to define a heavy infestation of nut-grass as one of over 3 gms dry foliage per sq.ft, and a light one as under 1 gm dry foliage per sq.ft.
(ii) The effect of the clipping regimes on the nut-grass

The incidental findings discussed in this section are of interest primarily because regular defoliation has often been suggested as a method of controlling nut-grass.

The most important point to note in this connection is that clipping must be repeated at least every week if any weakening of the tuber system is to be effected. At wider intervals, although the rate of recovery of the foliage is steadily reduced, the tuber numbers are increasing. It would appear that occasional defoliation such as this induces a form of dormancy in the tubers.

Further, the asymptotic nature of recovery from clipping (Table 12) means that optimism in the first few weeks of a defoliation programme is unjustified. After a rapid initial reduction in the apparent infestation, the remaining shoots appear to withstand the treatment for a very long period. This suggests that a certain proportion of the population may just be able to conduct enough photosynthesis in one week to replenish their food reserves.

If this is so, it would mean that twice-weekly clipping would be a very much more efficient way of exhausting the tubers than weekly clipping. Although at first sight such a procedure may appear to be hopelessly uneconomic, it is probable that it would achieve so much quicker results that in practice it would be cheaper than less frequent defoliations. This is shown in an experiment by Ranade and Burns (1925)(p.155), in which twice-weekly hoeing reduced the numbers of live tubers fourteen times more than did weekly hoeing. However, this process took ten months, in the first six of which neither regime more than halved the numbers of live tubers.

The same two authors showed that defoliation with a fork so as to remove the basal swelling of the plant, which lies just beneath the soil surface, is far more efficient in reducing aerial growth than is severing at ground level. There was no greater kill of tubers, however.

The curious feature which emerges from this work is that hoeing at intervals of about three weeks, which is perhaps the most commonly practised form of control in market gardens, is one of the worst things which could be done, both because of the amount of competition resulting to the current crop, and the increase in tuber numbers. It is in fact a compromise between
the high cost of frequent hoeing and the prospect of unlimited spread of the weed by both tubers and seeds. It is unfortunate that it appears to correspond to the point at which the weed offers greatest competition with the crop.

The urgent need for a complete and drastic form of control is therefore clear.

A CULTURAL METHOD FOR THE CONTROL OF NUT-GRASS—A PRELIMINARY TRIAL

A recent review of the various methods attempted to control nut-grass is given by Sparrow (1958). Of these methods, the most effective at present in use is described by Toms (1957). It is used in the Sudan Gezira scheme, and consists of dry season cultivation by means of a specially designed blade, 9' 6" long, which is drawn transversely through the soil at a depth of 1 ft by means of a crawler tractor. This process need only be repeated every eight years and is thus a very cheap way of controlling both nut-grass and Cynodon dactylon. Different explanations are put forward to account for the effectiveness of this method, the most likely being that of Andrews (1940) who performed the experiments which led to its adoption. These showed that tubers with their roots attached will rapidly die in soil containing less than 8% water; the permanent wilting point for nut-grass in this soil being about 17%. Other experiments showed that tubers exposed to the sun died within fifteen days unless their roots had access to a supply of water. Since the top 12" of the Gezira soil after a dry fallow contains only 7-11% water, whereas the lower depths still contain up to 24%, and since nearly all the nut-grass tubers occur in the top 12", while their roots penetrate to 5 ft, Andrews concluded that the tubers were surviving the dry season by drawing up water from below, and that severing their roots at a depth of 12" would therefore cause their death. Early trials with a disc plough proved this to be the case and led to the design of the instrument mentioned above, which does not allow any tuber roots to escape being broken.

The above workers emphasise, then, that in the Sudan, nut-grass control can easily be effected by a single operation in the dry season. Earlier workers in Western India, however, where the rainfall regime is much more like that of Trinidad, came to rather different conclusions (Ranade and Burns, 1925).
They also concluded that dry season cultivation was the most promising way of eradicating the weed, but they considered that, after ploughing, it was necessary to repeatedly stir and pulverise the soil in order to bring the tubers in turn up to the surface. They imply that sunlight (as opposed to mere heat) is important in accelerating the death of the tubers, although there is little evidence for this. In the first year of an experiment on dry season cultivation very little tuber mortality occurred; the following year, however, when the cultivations were repeated at twice-weekly intervals until the rains began in June, a complete kill was obtained.

In view of these findings in the Sudan and India, it was decided to conduct a rough trial to see whether the Trinidad dry season would be severe enough to permit the use of these cultural control methods. Figures for available soil moisture (i.e. that in excess of the permanent wilting point for maize) given by Hardy (1946) for the I.C.T.A. soils for each month of the year were much higher than those given by Andrews for the Sudan. (This is assuming that Andrews' figure of 17% for "soil moisture at cessation of growth" represents the permanent wilting point of the soil. Even so, the permanent wilting point found with maize may not be the same as that found with nut-grass: see Appendix 2.) Nevertheless, a field trial was considered to be the only way of finding out whether the method would work in practice. Andrews' method, i.e. a single deep ploughing, was chosen, since it was simpler than that of Ranade and Burns and because the principle of it appeared the more convincing.

Accordingly, a heavily-infested site was found on a piece of uncultivated land which was once part of a cocoa field and whose soil was similar to that of the previous experiment. (Actually the second site mentioned under "Preliminary Work".) The site was overgrown with Bhaji (Amaranthus sp.) and other weeds, including patches of Cynodon dactylon. The best time to do the ploughing was taken to be the beginning of March since, judging by past rainfall records, this date would allow the maximum period for drying out of the soil prior to ploughing, whilst still leaving a clear month before the rains for the tubers to die. Since only a very substantial kill of the weed would be of interest, it was not considered necessary to randomise or to mark out accurately the experiment. There were, however, six replicates, each consisting of three strips, 5 yds long, straddling the known line of very dense
infestation. One of these strips consisted of four furrows ploughed with a mouldboard plough, whose maximum depth of penetration was about 8"; the second strip of four furrows was ploughed with the 26" diameter disc plough, which did a much better job but which probably did not penetrate to the required 12" all the time; while the third strip was left unploughed as a control. All the ploughing was done on March 9th. The furrows produced by the mouldboard plough were later compressed by the tractor wheels, which probably hindered the drying-out of these plots. Immediately after the ploughing, eight samples of soil were taken from the furrow-walls at varying depths for an estimate of water content. The mean result of this was 15.03% (S.E. ± 1.7%, 7 d.f.), the permanent wilting point being later determined as 7.02% for both nut-grass and maize. At this water content it would not have been feasible to hand-dig the soil instead of ploughing; it was too hard.

Within a week of ploughing, the great majority of the exposed tubers on all the ploughed plots had shrivelled right up; later they became papery and were clearly dead. By March 17th, although there had been very little rain, nut-grass shoots began to sprout on the mouldboard-ploughed plots. Later, a few shoots appeared on the disc-ploughed plots. 1.58 inches of rain fell on April 7th breaking down the clouds somewhat, but the first rains to really soak the upper soil layers fell between April 22nd and 23rd (1.69 inches in all). On April 25th, in order to remove the weed growth on the control plots and to stimulate the tubers on them to sprout, the central part of every plot was rotary-hoed. By May 2nd there was a considerable amount of nut-grass growing on every plot and quadrat counts of shoots taken on May 8th gave the results shown in Table 11.

<table>
<thead>
<tr>
<th>Replicate number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disc ploughed</td>
<td>16</td>
<td>28</td>
<td>27</td>
<td>89</td>
<td>38</td>
<td>5</td>
<td>33.8</td>
</tr>
<tr>
<td>Mouldboard pl'd</td>
<td>68</td>
<td>41</td>
<td>50</td>
<td>33</td>
<td>19</td>
<td>19</td>
<td>38.3</td>
</tr>
<tr>
<td>Control</td>
<td>31</td>
<td>27</td>
<td>95</td>
<td>52</td>
<td>35</td>
<td>20</td>
<td>43.3</td>
</tr>
</tbody>
</table>

From this table it is clear that a single ploughing at the beginning of March does not give satisfactory control of nut-grass; furthermore, this trial was conducted in a dry season of exceptionally low rainfall, so that in
a normal year an even poorer kill might be expected. Although some of the nut-grass plants surviving on the ploughed plots may have arisen from tubers lying below the ploughing depth (this is almost certainly the case with the shoots which appeared before the rains began), many of the shoots, on excavation, proved to have come from quite superficially placed tubers. These had probably lain within the very large clods which were brought up by the plough and thus escaped desiccation. If so, this would mean that Ranade and Burns' technique of deep ploughing followed by further repeated cultivation to expose more tubers to the sun would be more effective.

Table 12 summarises the data relevant to these three attempts at cultural control of nut-grass.

Table 12. Results of three attempts at cultural control of nut-grass

<table>
<thead>
<tr>
<th>Place</th>
<th>Dry season climatic data (approx.)</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Length (months)</td>
<td>Mean rainfall (inches)</td>
</tr>
<tr>
<td>Surat, INDIA</td>
<td>5</td>
<td>under 5</td>
</tr>
<tr>
<td>Gezira, SUDAN</td>
<td>8</td>
<td>none</td>
</tr>
<tr>
<td>I.C.T.A., TRINIDAD</td>
<td>5</td>
<td>4.58 (1960) (mean)</td>
</tr>
</tbody>
</table>

CONTROL: - RECOMMENDATIONS

Combining the knowledge obtained from these experiments and from the literature, it is possible to make tentative recommendations for the control of nut-grass under tropical moderate-high rainfall conditions.

Until such a time as a satisfactorily-translocated herbicide comes on to the market at an economic price, it is wise for the farmer whose land is prone to nut-grass infestation to try to arrange his cultivations so as to hinder the nut-grass in every way possible. This is most likely to be achieved by:

1. Repeated deep ploughing in the dry season, provided that the soil is dust-dry.
2. The growing of dense, smothering cover crops in the wet season, which prevent the increase in tuber numbers (Sparrow, 1958).

3. Hoeing twice weekly, if this is considered economic.

Meanwhile, the most important thing to avoid is occasional (notably monthly) cultivation, especially rotary hoeing, in the wet season. This is guaranteed to increase the infestation more rapidly than any method known to the author.

It is emphasized that these recommendations, even if put into practice with great thoroughness, cannot at this stage be expected to do very much more than prevent the spread of the weed. Whether they could be justified economically for any but the most valuable crops is therefore very doubtful.

SUMMARY

1. Some features of associations of nut-grass (Cyperus rotundus L.) on the I.C.T.A. College lands are reported.

2. An experiment was performed, which suggested that, over the range of nut-grass infestations covered, the weed reduced lettuce yields by about a third. Cowpea yields were reduced by a quarter, on unfertilised plots only.

3. In the same experiment it was found that removal of the aerial parts of the weed only weakens the tuber system if performed as often as once a week. With less frequent defoliation, the tubers continue to multiply.

4. An attempt to control the weed by a single deep ploughing in the dry season gave a suggestion of only a small kill of tubers, despite ideal weather conditions.

ACKNOWLEDGEMENTS

The author is glad to express his thanks to Mr P.T. Richards for his help in supervising the project; to Mr G.B. Hodnett for advice in statistical matters; to Mr J.S. Campbell for recommending suitable test crops for the first experiment; to the staff of the Botany department who worked enthusiastically on the experiment; to Dr H. Vine and the staff of the Soils department for carrying out wilting-point determinations; to Mr Brian Honess, a fellow-student working on the same weed, for useful discussion; and to Miss I. Assing for typing the report.


Ranade, S.K. and Burns, W., 1925. Mem. Dept Agric. in India, 8, 99.


Appendix I. Soil and climate data

Soil: this profile description was made from a pit dug on the eastern edge of the experimental area of the main experiment, on May 7th. The soil of the deep ploughing experiment may be regarded as very similar.

History of site: the site had been cleared from banana cultivation in November 1959 and rotary hoed on December 12th. Since then, it had not been disturbed and when this description was written it was covered with weeds, notably Euphorbia hypericifolia, Sida rhombifolia and a grass, Chloris sp.

Profile description to 12"

0-3" - Light brown sandy clay loam, good crumb structure, many roots, arthropods.

3-9" - Pale yellow-brown sandy clay loam, blocky. Occasional roots.

9-12" - Deeper yellow-brown sandy clay loam, blocky, with gravel (schist?) particles. Occasional roots.

Topography: elevation 40 ft, aspect south, slope gentle.

Soil series: St Augustine. Major group: immature Latosol.

Drainage conditions: free.

Parent material: transported schist.

Climate: mean total rainfall (1922-59): 69".

Months with less than 4" mean rainfall: January, February, March, April.

Total mean rainfall of these months: 7.8". May mean: 4.91".

Mean maximum temperature: between 85 and 88°F for every month.

Mean minimum temperature: between 68 and 72°F for every month.

Relative humidity: 4 p.m. mean monthly figure is between 53% and 59% for January-May. For June-December it is between 60% and 67%. In early hours of morning (i.e. 1 a.m. till 7 a.m.) RH is about 96% all the year round.
Before conducting the experiment on deep ploughing, a wilting-point test was done to see whether the wilting-point of nut-grass was any different from that of maize (Zea mais), the test plant normally used.

Three soils were used, being the Soils department samples for the Montserrat, Princes Town and River Estate series. The normal technique with 50-cigarette tins was used, there being two replicates of every combination of the three soils and two test plants. The soils were first wetted to about field capacity and then placed in a cigarette tin with three maize seeds, three large nut-grass tubers (each over 0.3 g.) or three small (each under 0.3 g.) tubers. Total, eighteen tins. When shoots had appeared in all the tins the surfaces of the soils were waxed. The maize was regarded as permanently wilted (i.e. not recovered at 8 a.m.) after two weeks; the nut-grass took several days longer, the end-point being rather uncertain. After wilting the water content of the soils was found to be as follows.

(Percentages. Mean of two replicates.)

<table>
<thead>
<tr>
<th>Soil series</th>
<th>Nut-grass Large tubers</th>
<th>Nut-grass Small tubers</th>
<th>Maize</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Montserrat</td>
<td>25.0</td>
<td>19.2</td>
<td>21.7</td>
<td>21.9</td>
</tr>
<tr>
<td>Princes Town</td>
<td>18.1</td>
<td>17.2</td>
<td>24.9</td>
<td>20.1</td>
</tr>
<tr>
<td>River Estate</td>
<td>10.9</td>
<td>11.7</td>
<td>15.2</td>
<td>12.6</td>
</tr>
<tr>
<td>Mean</td>
<td>18.0</td>
<td>16.0</td>
<td>20.6</td>
<td>18.2</td>
</tr>
</tbody>
</table>

Analysis of the angles corresponding to these percentages shows that the mean figure for nut-grass is just significantly lower, on the Princes Town and River Estate soils, than for maize. More replicates are required in such experiments.

A similar wilting-point determination on St Augustine series soil taken from the site of the deep ploughing experiment gave the following result.

<table>
<thead>
<tr>
<th>Replicate No.</th>
<th>Nut-grass</th>
<th>Maize</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.62</td>
<td>7.14</td>
</tr>
<tr>
<td>2</td>
<td>7.14</td>
<td>6.77</td>
</tr>
<tr>
<td>3</td>
<td>7.30</td>
<td>7.19</td>
</tr>
</tbody>
</table>

The mean result is 7.02%. There is clearly no significant difference between the nut-grass and the maize.
Appendix 3. Skeleton analysis of variance for the main experiment

<table>
<thead>
<tr>
<th>Source</th>
<th>Degrees of freedom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blocks</td>
<td>2</td>
</tr>
<tr>
<td>Fertiliser v none</td>
<td>1</td>
</tr>
<tr>
<td>Error (a)</td>
<td>2</td>
</tr>
<tr>
<td>Main plot total</td>
<td>5</td>
</tr>
<tr>
<td>Nut-grass levels</td>
<td>3</td>
</tr>
<tr>
<td>Ditto x fertiliser level</td>
<td>3</td>
</tr>
<tr>
<td>Error (b)</td>
<td>12</td>
</tr>
<tr>
<td>Grand total</td>
<td>23</td>
</tr>
</tbody>
</table>

(On the lettuce experiment there were only 11 d.f. for error of subplots, owing to a missing plot which was cut in error.)