Computational Analysis of *Sorghum bicolor* Response to *Striga hermonthica* Infestation

By

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In Partial Fulfilment of the Requirement for the Award of Postgraduate Diploma in Computer Science

SEPTERMBER, 2000

CERTIFICATION

This is to certify that this project work was carried out by Musa G.M. Kolo, PGD/MCS/98/99/831, of the Department of Mathematics/Computer Science, Federal Unviersity of Technology, Minna

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External Examiner	Date

ACKNOWLEDGEMENT

I am grateful to Dr. S.A. Reju, my supervisor, for putting me hrough in making this project write-up a reality. To my class-nates Jacob and Ajibade for the academic interaction and A. Idris or the field work, I am grateful.

With affection to my wife, Grace and Children, Joanna, Enoch
nd Salome

ABSTRACT

There is intense application of Science and Technology in Agricultural pro-
ıction systems. The use of computers in agriculture for data analysis is
e of the many ways it is applied in this field. Data generated through a
ndomized complete block design of sowing six varieties of sorghum (KSV
KSV 8, NR 71182, NR 71176, ICSV 111 and local) at four different times
5 and 27 June and 9 and 21 July) were computer analyzed. The analysis
ıs made possible by writing a specific program for the set of data and run
ing Genstat statistical package for DOS. Results and output are presented.

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ever, germination of seeds requires exposure to an exogenous germination stimulant after an environmental conditioning period in which the seeds imbibe water. On germination, the radicle of the *Striga* seedling grow towards the root of the host crop and eventually attached to it. The seeds are stimulated to germinate in the presence of a chemical substance (strigol) secreted by the host crop. After successful attachment, developing *Striga* plant grows underground for 4-7 weeks prior to emergence. The *Striga* plant is totally dependent upon the host plant for its survival before and after emergence from the ground. It could therefore cause severe damage to the host crop even before the shoot appears above the ground.

The effect of *Striga* on the host crop is more than the removal of vater and nutrients because once established it becomes a meta-oolic sink for the carbohydrate produced in the host. The at-endant result of this on the host crop is reduced plant height, he leaves are chlorotic, which results in reduced yield and in ome cases death of the host crop. *Striga* has been shown to ause disease in the host by inducing enzymes and plant hor-none changes thereby disrupting host water relation and reduced arbon fixation below the expected (Pieterse, 1985). The effect of ttack by *Striga* on sorghum has been reported by several au-nors (Parker, 1978, Doggette, 1988). It is known to cause stunt-ng of the shoot, reduction of vigour and failure of panicle forma-on. Chlorotic blotches and necrosis on the foliage also occur nd in extreme cases, total collapse and death of the plant. *Striga* narkedly alters the architecture of sorghum plant as a result of cultural importance, but those that parasitize crop plants can be extremely damaging. Yield losses on cereals attributable to infection by *Striga* may reach 100%, and infestation may be so great that continued cereal production becomes impossible and farmers abandon the fields. In West Africa alone, it is estimated that 40m ha in cereal production are severely infested by *Striga* spp. and nearly 70 million ha are moderately infested.

The response of sorghum to *Striga* attack depends on crop variety. Sorghum promotes seed production by *Striga* While some varieties support low levels of *Striga*, others are of medium to high susceptibility. Elemo and Ogungbile (1995) found 70-90% yield losses in improved cultivars of sorghum as compared with 40-50% for the local in northern Guinea savanna of Nigeria. The high frequency of sorghum cropping provides suitable conditions for *Striga* to build up and maintain high levels of infestation.

The severity of a given *Striga* infestation on sorghum yield depends on crop variety and environmental factors. Tolerant varieties reduce the severity of a given *Striga* attack, but incidence which relates to the number of emerged and reproducing *Striga* may be similar to that of succeptible varieties while varieties resistant to striga attachment have a reduced incidence and severity.

Sorghum plants show characteristic symptom once they are attacked by *Striga*. Symptoms of parasitism are often dramatic but nondescript, resembling drought stress, nutrient deficiency and vascular disease. Symptoms could best be evaluated at grain filling. Damage from *Striga* on the host plant starts from attachment and is visible before emergence of the parasitic plant. The evaluation of damage symptoms is a better indication of yield losses than counts of emerged *Striga* shoots. Response to *Striga* by sorghum may be grouped into:

(i) Symptom description. This include leaf blotch, necrotic spots, leaf scorch, premature death of leaves. This is rated on a scale of say 0-9, 0 indicates no damage while 9 indicates severe damage.

(ii) Height of host plant which measures the degree of stunted growth.

(iii) Number of ear formation which will show crop grain yield (kg/ha).

(iv) The number of *Striga* shoots observed above-ground/m^2 with or without reproductive structures.

2.4 MATERIALS AND METHODS

An experiment was conducted during the 1999 wet season (June - November) on a *Striga* infested land located on the outskirts of Minna (9^0 37 'N, 6^0 32 'E).

Six sorghum varieties (KSV 4, KSV 8, NR 71182, NR 71176, ICSV III and local) were planted at four different times (15 and 27 June, 9 and 21 July) at intervals of two weeks. Each plot measured 4 x 15m with five ridges (90 cm apart). The seeds were sown at 30cm apart and later thinned to three plants per stand at three weeks after sowing. The experiment was a Randomize Complete Block design with three replicates. Weeding was manually done with the hoe at four and eight weeks after each planting date.

Data were taken on both *Striga* and sorghum plants. The number of *Striga* shoots per sorghum stand and per plot were noted at 10 weeks after sowing. Number of days to first *Striga* shoot emergence was also noted. Sorghum symptoms as indicated by the number of scorched (chlorotic) and stunted plants per plot was noted at 18 weeks after sowing. This was achieved using a scale of 1-9 were 1 represented normal sorghum growth with no visible symptoms and 9 represented complete leaf scorching, causing premature death of leaves. Sorghum plant height was taken from ground level to ear neck at 10 and 18 weeks after sowing. Crop ear length was also taken at 18 weeks after sowing. Sample heights of ten plants were taken and the average used for analysis. Crop grain yield was not obtained due to insect pest attack, smut disease and bird damage. However, 100 seed weight was noted.

The data were keyed in using the "Blackbeard" Editor software coding the data file. They were then analyzed using Genstata statistical package version 5.2.

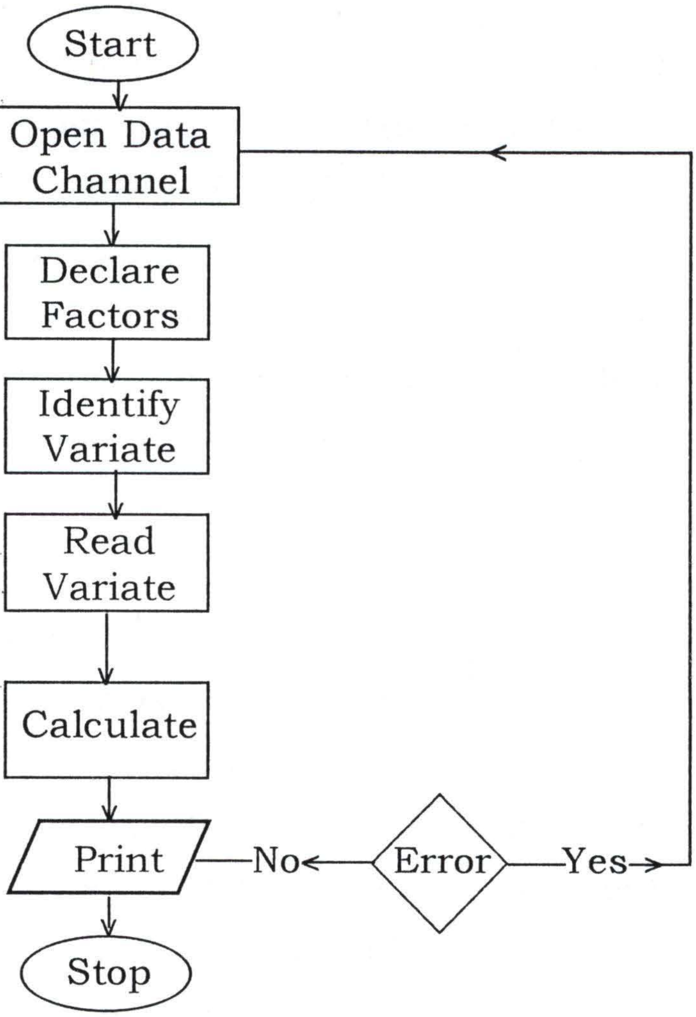
a specific problem(s) can be solved in a sequence. It is important to state here that an algorithm must be definite and effective. In other words, the stepwise instructions should be clear and not ambitious and must be executable. In addition, the instructions are not indefinite, but must terminate after a given number of steps of instructions.

There are many ways to describe algorithm. The use of flow charts to describe algorithm is an improvement over that of natural languages in that it is in graphical form of notations. Each of the process is placed in a box which are of different shapes depending on the type of instruction and arrows are used to indicate the direction of flow of instructions.

To use a computer to perform calculations on a set of data, as in this study, one has to compose instructions in a language the computer will understand and get the data into the computer. In this work, a set of such instructions (Program) is constructed using the "GENSTAT LANGUAGE". The programme allows the user to specify what one wants precisely.

3.2 ALGORITHM FLOW CHART

Fig. 1.1 Genstat Program analysis flow chart



The "Start" terminal symbol in the program is the first module which indicates the commencement of the program. The same symbol shows that the program has come to an end, after which it begins to carry out the instructions. The rectangular boxes indicate the process symbol according to the details in the box. Whenever there is an error/errors in the data input, or program a decision has to be made either to calculate or not.

Chapter Four

4.1 RESULTS AND DISCUSSION OF COMPUTATION

4.2 STRIGA HERMONTHICA POPULATIONS

4.2.1. PLANTING DATE

Table 4.1 shows that *Striga* shoot number per plot ($8m^2$) rose from 55 to 77 when planting of sorghum was delayed from 15 to 27 June, and then declined subsequently from 62 to 22. However, only the last planting date (21 July) has significantly less number of *Striga* shoots than all other planting dates which did not differ greatly.

Table 4.1: The influence of date of planting and sorghum varieties on *Striga* hermonthica shoot population per plot ($8m^2$).

	SORGHUM VARIETIES						
Planting Date	KSV8	KSV4	NRS71176	NR71182	ICSV111	Local	Mean
15 June	101.7	31.0	51.3	18.3	35.7	89.0	54.5
27 June	53.0	80.7	70.0	37.0	136.3	84.0	76.8
9 July	36.0	62.0	66.3	35.3	97.7	75.7	62.2
21 July	35.7	6.0	19.7	5.3	11.3	53.7	21.9
Mean	56.6	44.9	51.8	24.0	70.2	75.6	

LSD (0.05)	Planting Date	=	25.7
	Sorghum Varieties	=	31.5
	Interaction	=	62.9

4.2.2. SORGHUM VARIETY

The least mean *Striga* shoot populations (24) was found in sorghum variety NR 71182 which was greatly less than those of KSV8, CSV 111 and the local, but not with KSV 4 and NR 71176 (Table 4.1)

.2.3. PLANTING DATE X SORGHUM VARIETY

It is obvious (Table 4.1) that planting of sorghum on 21 July upported the least *Striga* population for all the varieties. Planting of sorghum on 21 July had significantly less populations of *triga* than planting varieties KSV8 and KSV 4 on 15 June and 7 June respectively. The same is true with planting variety ICSV 11 on either 27 June of 9 July. Other sorghum varieties (NR 1176, NR 71182 and the local) did not greatly differ in *Striga* hoot emergence in respect to date of planting.

3 SEVERITY OF ATTACK OF SORGHUM

3.1 DATE OF PLANTING

The planting date of sorghum did not have significant effect on *riga hemonthica* attack as severity score varied between 7.6 - 3 on a scale of 0-10 (Table 4.2)

3.2 SORGHUM VARIETIES

Table 4.2 shows that severity of *Striga hermonthica* attack score sorghum did not differ greatly, it ranged from 7.0 - 9.0. The verity of attack of *Striga* on sorghum was similar. Similarly, ere was no significant interaction between the treatments.

Table 4.2: Effect of date of planting and sorghum varieties on severity of *Striga hermothica* attack on sorghum

	SORGHUM VARIETIES						
Planting Date	KSV8	KSV4	NRS 71176	NR71182	ICSV 111	Local	Mean
15 June	8.3	8.3	9.0	5.3	8.0	7.0	7.7
27 June	8.3	9.0	7.7	8.3	7.7	9.0	8.3
9 July	7.7	7.7	9.0	9.0	8.3	8.3	8.3
21 July	9.0	7.0	7.7	7.0	7.0	7.7	7.6
Mean	8.3	8.0	8.3	7.4	7.8	8.0	

4.4 EAR FORMATION

4.4.PLANTING DATE

The average number of days to ear formation were significantly earlier than each other such that the crop planted latest (21 July) formed ears earliest (average of 78 days) (Table 4.3.) On the contrary, the one planted on 27 June took the longest time to form ears (average of 111 days). However, this did not follow a definite pattern of duration of ear emergence.

Table 4.3 The effect of planning date and crop variety on days to ear formation of sorghum.

	PLANTING DATE				
Crop Variety	15 June	27 June	9 July	21 July	Mean
KSV 8	105.0	111.0	81.3	75.7	93.2
KSV 4	92.7	108.0	105.3	66.0	93.0
NR 71176	99.3	120.0	87.0	76.0	95.6
NR 71182	100.0	110.7	85.0	86.3	95.5
ICSV 111	89.0	107.0	86.0	68.7	87.7
Local	105.0	112.0	97.3	93.3	101.9
Mean	98.5	111.4	90.3	77.7	

LSD (0.05) Planting Date = 6.1
Crop Variety = 7.4
Planting Date and Crop Variety = 14.9

4.4.2 SORGHUM VARIETIES

The local variety took the longest time to reproduce (102 days) while ICSV 111 took the least (average of 88 days) (Table 4.3.) However, only KSC 8, KSV 4 and ICSV 111 matured significantly earlier than the local variety.

4.4.3 PLANTING DATE/SORGHUM VARIETIES

Results of the interaction between planting date and crop variety as indicated in Table 4.3 shows that 21 July planting produced plants that formed ears earliest irrespective of the variety. Generally, the time to ear formation increased form 15 to 27 June planting and subsequently reduced as planting date was delayed.

4.5 DISCUSSION

4.5.1 *STRIGA HERMONTHICA* POPULATIONS

The fewer populations of *Striga hmr onthica* due to delayed planting found in this study confirms the work of Hess and Williams, 1995; Toure *mt al.* 1996: This might be due to delayed *Striga* seed stimulations for germation by the host crop due to high soil moisture content at that time of the year. The agronomic implication is that sorghum varieties that mature early could be planted late (about third week of July) in this area to avoid *Striga* infestation, and yet obtain a good yield.

It is obvious that different sorghum varieties respond differently to *Striga hm onthica* attack as seen in this study. A farmer should therefore look for sorghum varieties that show some degree of resistance to *Striga* infestation.

4.5.2 SEVERITY OF ATTACK OF SORGHUM

Results show that irrespective of time of planting and the sorghum variety used the severity score was not much. However, this can be greatly misleading due to the fact that the damage caused by *Striga* is both underground and above ground. Secondly, since this is based on personal judgement it could be sentimental.

4.5.3 SORGHUM EAR FORMATION

The reducing time of ear formation with planting date might be due to the longer period the crops planted early had for vegetable growth since they responded to day length. The crops planted early were seen to be much taller than those planted late.

The varietal difference observed in duration to ear formation could be attributed to inherent characteristics which may explain why the local variety took the longest time to reach reproductive stage.

4.6 PROGRAM OUTPUT

The program output of the Genstat implementation is reported below.

```
open 'a:strigami.dat';channel=2;filetype=i
units [nvalues=72]
factor [levels=3;values=(1,2,3)24] reps
factor [levels=4;values=18(1,2,3,4);labels=!T('june15','june27',\
        'july9','july21')]plandate
factor [levels=6;values=3(1...6)4;labels=!T('variety1','variety2',\
        'variety3','variety4','variety5','variety6')]varietis
read [channel=2;serial=yes] plantht,daysear,sevescor,stripsta,\
     striplot,earlenth
148      94   170
106      73   150
 92     150   103
 67     140    96
 92     130   131
161     141   210
129     112    89
126     169   172
113     129   105
 72     219   102
102     157    77
114     129   132
130      91   131
 91     113    71
 60     126   154
 80     115   123
120     116   152
150      99   117
 88     114   160
101      96   122
 82      51   120
 71      78    84
132     120   110
 91      63   190
 :

    Identifier  Minimum       Mean   Maximum     Values    Missing
       plantht     51.0      116.9     219.0         72          0
105      105   105
 96       91    91
 88      105   105
 96       96   108
 88       91    88
105      105   105
108      120   105
108      108   108
120      120   120
116      108   108
108      108   105
120      108   108
 69       79    96
110      110    96
 69       96    96
 69       90    96
 69       79   110
105       91    96
 65       71    91
 65       67    66
```

```
65    92    71
69    99    91
71    67    68
98    91    91
:
        daysear      65.00      94.49     120.00          72          0
8   8   9
8   9   8
9   9   9
6   5   5
7   9   8
7   5   9
9   9   7
9   9   9
9   7   7
7   9   9
7   7   9
9   9   9
9   5   9
7   9   7
9   9   9
9   9   9
7   9   9
9   9   7
9   9   9
7   9   5
9   9   5
9   7   5
7   9   5
9   9   5
:
       sevescor      5.000      7.972      9.000          72          0
5   3   10
3   2    2
4   3    3
5   2    2
3   2    2
3   3    2
3   3    4
3   3    2
2   4    2
8   2    2
4   5    0
3   4    4
4   2    4
3   6    3
4   4    2
2   3    5
5   5    4
3   1    2
3   3    4
2   4    3
4   2    3
3   2    3
4   2    5
5   3    4
:
```

```
        stripsta      0.000      3.306     10.000        72        0
122     73     110
 68     10      15
 95     28      31
 28     24       3
 82     15      10
127     50      90
 30     72      57
189      0      53
 69     72      69
 72     21      18
248     70      91
171     41      40
 37     21      50
122     26      38
 50     59      90
 50      7      49
 71     60     162
180      6      41
 40     61       6
 14      4       0
 40     12       7
  7      9       0
 16      9       9
118     39       4
:
        striplot      0.00      53.86     248.00        72        0    Skew
28   29   23
21   39   23
25   21   21
21   35   21
21   20   24
19   32   30
35   21   21
23   22   20
20   21   23
21   22   23
30   40   31
23   25   24
31   29   31
21   30   23
29   23   31
35   29   31
23   27   29
32   30   31
25   35   32
21   22   30
23   35   24
22   22   20
21   39   23
32   31   32
:
        earlenth    19.00     26.42     40.00        72        0
treatments reps+plandate*varietis
anova[fprob=yes]plantht,daysear,sevescor,stripsta,striplot,earlenth
```

***** Analysis of variance *****

Variate: plantht

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
reps	2	6397.	3198.	2.93	0.063
plandate	3	5601.	1867.	1.71	0.178
varietis	5	6681.	1336.	1.22	0.313
plandate.varietis	15	15174.	1012.	0.93	0.542
Residual	46	50192.	1091.		
Total	71	84045.			

* MESSAGE: the following units have large residuals.

units 29	87.2	s.e. 26.4
units 72	64.2	s.e. 26.4

***** Tables of means *****

Variate: plantht

Grand mean 116.9

reps	1	2	3
	104.9	117.7	128.0

plandate	june15	june27	july9	july21
	125.2	124.9	113.3	104.1

varietis	variety1	variety2	variety3	variety4	variety5	variety6
	121.3	115.8	107.1	103.9	119.9	133.1

plandate	varietis	variety1	variety2	variety3	variety4	variety5	variety6
june15		137.3	109.7	115.0	101.0	117.7	170.7
june27		110.0	155.7	115.7	131.0	112.0	125.0
july9		117.3	91.7	113.3	106.0	129.3	122.0
july21		120.7	106.3	84.3	77.7	120.7	114.7

*** Standard errors of differences of means ***

Table	reps	plandate	varietis	plandate varietis
rep.	24	18	12	3
s.e.d.	9.54	11.01	13.49	26.97

***** Analysis of variance *****

Variate: daysear

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
reps	2	473.86	236.93	2.86	0.068
plandate	3	10869.04	3623.01	43.71	<.001
varietis	5	1292.24	258.45	3.12	0.017
plandate.varietis	15	2534.04	168.94	2.04	0.033
Residual	46	3812.81	82.89		
Total	71	18981.99			

* MESSAGE: the following units have large residuals.

units 51 21.7 s.e. 7.3

***** Tables of means *****

Variate: daysear

Grand mean 94.5

reps	1	2	3
	90.9	95.7	96.8

plandate	june15	june27	july9	july21
	98.5	111.4	90.3	77.7

varietis	variety1	variety2	variety3	variety4	variety5	variety6
	93.2	93.0	95.6	95.5	87.7	101.9

plandate	varietis	variety1	variety2	variety3	variety4	variety5	variety6
june15		105.0	92.7	99.3	100.0	89.0	105.0
june27		111.0	108.0	120.0	110.7	107.0	112.0
july9		81.3	105.3	87.0	85.0	86.0	97.3
july21		75.7	66.0	76.0	86.3	68.7	93.3

*** Standard errors of differences of means ***

Table	reps	plandate	varietis	plandate varietis
rep.	24	18	12	3
s.e.d.	2.63	3.03	3.72	7.43

***** Analysis of variance *****

Variate: sevescor

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
reps	2	5.528	2.764	1.57	0.220
plandate	3	9.500	3.167	1.80	0.161
varietis	5	7.444	1.489	0.84	0.526
plandate.varietis	15	38.333	2.556	1.45	0.166
Residual	46	81.139	1.764		
Total	71	141.944			

```
* MESSAGE: the following units have large residuals.

*units* 38          -2.90    s.e. 1.06


***** Tables of means *****

Variate: sevescor

Grand mean  7.97

     reps          1         2         3
                8.13      8.21      7.58

 plandate    june15    june27     july9    july21
                7.67      8.33      8.33      7.56

 varietis variety1 variety2 variety3 variety4 variety5 variety6
              8.33      8.00      8.33      7.42      7.75      8.00

 plandate varietis variety1 variety2 variety3 variety4 variety5 variety6
   june15              8.33      8.33      9.00      5.33      8.00      7.00
   june27              8.33      9.00      7.67      8.33      7.67      9.00
    july9              7.67      7.67      9.00      9.00      8.33      8.33
   july21              9.00      7.00      7.67      7.00      7.00      7.67


*** Standard errors of differences of means ***

Table                    reps    plandate     varietis    plandate
                                                          varietis
rep.                       24          18           12           3
s.e.d.                  0.383       0.443        0.542       1.084



***** Analysis of variance *****

Variate: stripsta

Source of variation      d.f.        s.s.        m.s.    v.r.  F pr.
reps                        2       5.028       2.514    1.12  0.334
plandate                    3       0.500       0.167    0.07  0.973
varietis                    5       8.278       1.656    0.74  0.598
plandate.varietis          15      40.500       2.700    1.21  0.302
Residual                   46     102.972       2.239
Total                      71     157.278

* MESSAGE: the following units have large residuals.
*units* 3            4.10    s.e. 1.20
*units* 28           3.64    s.e. 1.20
*units* 33          -2.90    s.e. 1.20

***** Tables of means *****
```

Variate: stripsta

Grand mean 3.31

reps	1	2	3
	3.67	3.04	3.21

plandate	june15	june27	july9	july21
	3.28	3.22	3.44	3.28

varietis	variety1	variety2	variety3	variety4	variety5	variety6
	4.00	3.00	3.08	3.25	3.42	3.08

plandate	varietis	variety1	variety2	variety3	variety4	variety5	variety6
june15		6.00	2.33	3.33	3.00	2.33	2.67
june27		3.33	2.67	2.67	4.00	3.00	3.67
july9		3.33	4.00	3.33	3.33	4.67	2.00
july21		3.33	3.00	3.00	2.67	3.67	4.00

*** Standard errors of differences of means ***

Table	reps	plandate	varietis	plandate varietis
rep.	24	18	12	3
s.e.d.	0.432	0.499	0.611	1.222

***** Analysis of variance *****

Variate: striplot

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
reps	2	36814.	18407.	12.38	<.001
plandate	3	29084.	9695.	6.52	<.001
varietis	5	20684.	4137.	2.78	0.028
plandate.varietis	15	27780.	1852.	1.25	0.275
Residual	46	68386.	1487.		
Total	71	182749.			

* MESSAGE: the following units have large residuals.

units 22	76.9	s.e.	30.8
units 31	80.3	s.e.	30.8
units 51	74.7	s.e.	30.8
units 52	72.9	s.e.	30.8

***** Tables of means *****

Variate: striplot

Grand mean 53.9

reps	1	2	3
	85.2	32.9	43.5

plandate	june15	june27	july9	july21
	54.5	76.8	62.2	21.9

varietis	variety1	variety2	variety3	variety4	variety5	variety6
	56.6	44.9	51.8	24.0	70.2	75.6

plandate	varietis	variety1	variety2	variety3	variety4	variety5	variety6
june15		101.7	31.0	51.3	18.3	35.7	89.0
june27		53.0	80.7	70.0	37.0	136.3	84.0
july9		36.0	62.0	66.3	35.3	97.7	75.7
july21		35.7	6.0	19.7	5.3	11.3	53.7

*** Standard errors of differences of means ***

Table	reps	plandate	varietis	plandate varietis
rep.	24	18	12	3
s.e.d.	11.13	12.85	15.74	31.48

***** Analysis of variance *****

Variate: earlenth

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
reps	2	134.08	67.04	2.96	0.062
plandate	3	176.61	58.87	2.60	0.064
varietis	5	198.00	39.60	1.75	0.143
plandate.varietis	15	571.56	38.10	1.68	0.089
Residual	46	1043.25	22.68		
Total	71	2123.50			

* MESSAGE: the following units have large residuals.

units 5	9.46	s.e. 3.81
units 19	10.67	s.e. 3.81
units 68	9.46	s.e. 3.81

***** Tables of means *****

Variate: earlenth

Grand mean 26.42

```
 reps          1          2          3
           25.08      28.29      25.87

landate    june15     june27      july9     july21
           25.17      24.72      28.61      27.17

arietis variety1  variety2  variety3  variety4  variety5  variety6
           28.33     24.58     24.67     25.17     27.33     28.42

landate varietis  variety1  variety2  variety3  variety4  variety5  variety6
 june15              26.67     27.67     22.33     25.67     21.67     27.00
 june27              25.67     21.67     21.33     22.00     33.67     24.00
  july9              30.33     24.67     27.67     31.67     26.33     31.00
 july21              30.67     24.33     27.33     21.33     27.67     31.67

* Standard errors of differences of means ***

ole                   reps    plandate    varietis    plandate
                                                      varietis
).                      24          18          12           3
e.d.                 1.375       1.587       1.944       3.888

op

****** End of job.  Maximum of 14888 data units used at line 14 (369098 left)
```

(iii) The computer produces the results of data management with speed, a feature that is devoid in manual calculations.

(iv) The date of planting sorghum in this ecological zone can be manipulated to avoid *Striga hemothica* attack on it provided it is early maturing.

. Pieterse, A.H. (1985). Control of *Striga* at the level of the small scale farmer. FAO/DAU workshop on *Striga*. Yaounde, Cameroun. 23-27 September. 24-36.

). Press, M.C.J.M. Toutly, G.R. Stewart (1988). Gas exchange characteristics of Sorghum *Striga* host - parasite associated plant physiology. Weed Abstract Vol. 37 (1) 814-819.

.. Stephens, R.J. (1982) Theory and practice of weed control. The Macmillan Press Ltd. London. 215pp.

APPENDICES

Genstat Instructions (Program)

```
pen 'a:strigami.out';channel=3;filetype=o
py [print=s,o]3
pen 'a:strigami.dat';channel=2;filetype=i
nits [nvalues=72]
actor [levels=3;values=(1,2,3)24] reps
actor [levels=4;values=18(1,2,3,4);labels=!T('june15','june27',\
    'july9','july21')]plandate
actor [levels=6;values=3(1...6)4;labels=!T('variety1','variety2',\
    'variety3','variety4','variety5','variety6')]varietis
ead [channel=2;serial=yes] plantht,daysear,sevescor,stripsta,\
   striplot,earlenth
reatments reps+plandate*varietis
nova[fprob=yes]plantht,daysear,sevescor,stripsta,striplot,earlenth
top
```

```
)DDDDDDDDDDDDDDDDDDDDDDDDDDDD4Genstat 5CDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

 Genstat batch node

t 5  Release 2.2  (80386 based DOS PCs)        06-Sep-1900 22:26:25
ght 1990, Lawes Agricultural Trust (Rothamsted Experimental Station)

*********************************************************************
can use Genstat interactively in command-mode or in menu-mode.      *
are now in command-mode:                                            *
ype HELP for on-line help about the command language of Genstat;    *
ype STOP to finish;                                                 *
ype MENU to enter menu-mode - Genstat will prompt for information.  *
standard menu system covers some of the standard analyses that can  *
one in command-mode, and is designed so that you can extend it.     *
*********************************************************************

)DDDDDDDDDDDDDDDDDDD4Press F1 for help on windows , TAB to switch windowsC

 Genstat menu

)DDDDDDDDDDDDDDDDDDDDDDDDDDDD4Genstat 5CDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
 G22COMND:  copy of Genstat commands that do the operations;
 G22STORE:  quick-access binary storage of your data.

enu
ould you like to do next ?
    (null) chooses default response, if any;                 |
    help;  ?? lists current structures of allowed type;      |  Special
           ?code gives specific help, if any;                |  responses
    repeat the question;                                     |  to any
    return to previous layer of menus;                       |  question
    exit to command mode.                                    |

    input data
    calculate new data, edit data, or define groups
    display or summarize data in tables
    display data in pictures
    analyse data by standard statistical methods
    quit using menu system
)DDDDDDDDDDDDDDDDDDD4Press F1 for help on windows , TAB to switch window

s RETURN to continue*
```