CROP TECHNOLOGY 302, 1994

TITLE: Seed size differences and related germination characteristics

SPECIES: *Santalum spicatum*

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INTRODUCTION

The genus *Santalum* is a root parasitic tree or shrub. It contains about 25 species found in Australia, Indonesia and Oceania. Four species occur in W.A. these being, *Santalum.acuminatum, S.lanceolatum, S.murrayanum* and *S.spicatum* (Marchant and Wheeler 1987)

S.album is found mainly in India and in various institutions in W.A. This plant requires a host for growth to maturity and survival (Hutchins 1884 Rama.Rao 1904,1906)
S.lanceolatum is spread over the tropical parts of Australia. *S.murrayanum* is found in inland of Southern Australia. *S.spicatum* is also a root hemi-parasite associated with a range of hosts, and is slow growing, requiring around 60 - 90 years to be of a commercial size. It is well adapted to drought and its aromatic oils are highly valued.

These four, above all other *Santalum* species, are commercially significant and mostly are exported to countries overseas.

The connection with the host tree is an important one for these *Santalum* species. To survive in their early stage they need to get shade and nutrition from their hosts (Rai 1990)
Ninety seven percentage of seedlings initiate a haustoria, which does not necessarily make a connection, over the course of the first year (Nagaveni and Srimathi 1985)

There may be a correlation between the seed size and germination time and rate (Cideciyan and Malloch 1982)
In addition, Harper (1977) said seed size may control an adaptative condition which they can well establish and widely disperse. Seedling growth is affected by seed weights and/or emergence times.

We can determine the seed size by using Cotyledon area and weight, leaf area, root weight and overall seedling dry weight.

To determine and prove the above theories, four hypotheses have been established.

All four species (*S.album, S.lanceolatum, S.murrayanum, S.spicatum*) are used for this experiment overall. However in my section of this project only one species will be tested, this being *S.spicatum.*
The other three species are currently being studied by some of my associates.

The first aim is to analyze a significant difference in seed mass, diameter and length of seed within a species. Each seed of *S.spicatum* was individually weighed and measured (diameter and length/width). this was done before the seeds were transplanted. Each seed has been labelled so that its size and mass could subsequently be related to its own germination and seedling characteristics.

Secondly, we wish to find out the effects of time on the start of germination, rate of germination and final germination percentage depend on the seed size, so germination dates for every seeds were recorded when the hypocotyl first showed above ground or when the radicle emerged on the sand surface.

The third aim is to test the correlation between seed mass/size and growth rate, seedling leaf area and number, and height. Therefore the stem length, leaf numbers and the kernel's condition are measured weekly .
To support this experiment, the dry weight of the kernels and the shells are obtained, and also dry weight of roots, stems and kernels are taken to find out this correlation.

Finally, the data of growth rates of each species is collected and studied to find out any similarity of growth rate among the four *Santalum* species.

Through this we hope to find out more about these parasitic plants, so that we may better manage another of Australia unique and rich resources for now and for generations to come.

LITERATURE REVIEW

DESCRIPTIVE FEATURES OF SANDAL WOOD

The species of *Santalum* are distinguished by their variety in height, form, leaf shape, colour and fruiting patterns. Sandal wood produces flower buds at the age of three to four years, and the first seedcrop sets at six to seven years. The fruits mature usually in October and January and fall to the ground. The ripe fruit has a leathery tan-brown outer epicarp and a smooth round, inner nut or endocarp (Loneragan 1990)

The wood includes sapwood and heartwood. The heartwood and the roots contain the strongly aromatic Sandalwood oil.
The fine roots, which develop on the extensive lateral roots of the Sandalwood, produce a lateral haustorium with roots of other species. The haustoria are produced in large numbers, although the haustoria have only a limited functional existence.
Santalum spicatum, although capable of photosynthesis, is an obligate parasite, which can survive only by parasitising through the development of haustoria on a wide range of host species, usually of the genera *Eucalyptus* and *Acacia* (Loneragan 1990)

When plants are not attached to hosts, they display chlorotic symptoms similar to those observed in other plants when Nitrogen or trace elements are deficient (Wijesuriya 1984)

Development independent of a host plant is able to continue while the nutrient of the endosperm of the seed is available for the growth of the shoot above ground and the root system. Western Australian Sandalwood not only withstands drought, but may maintain growth during a dry season (Loneragan 1990)

DEFFERENCES IN SEED MASS, DIAMETER AND LENGTH OF SEED WITHIN A SPECIES .

Is there any significant difference in seedmass, diameter and length of seed within a species ? .

Several recent studies have demonstrated that seed mass may vary considerably within populations and within individual plants (Agren 1989, Janzen 1978)
Agren (1989) proved that seed size had been shown to be affected by, resource availability, position within the fruit and on the plant, defoliation and pollination throughness. Seed weight is not the only factor to be taken into account in considering the selection of seed characters through their

effect upon subsequent growth of the seedling. The chemical condition of the food reserves - starch, protein, oils, or wax - also play a part (Baker 1972)

The differences in seed weight are due to differences in the amounts of reserve substances (Wulff 1986)
Concerning seed size variation, Black (1958) has pointed out a larger seed with more stored food may have a selective advantage in the short growing season.

McWilliams (1967) suggests it is also possible that seed size is genetically linked with some other character that has a selective advantages.
Therefore seed variation within a species may have both a genetic and an environmental component.

AFFECT OF SEED SIZE ON GERMINATION TIME, RATE OF GERMINATION AND FINAL GERMINATION PERCENTAGE.

The hypothesis is that seed size does not affect the time of germination, rate of germination and final germination percentage, within a species.

McWilliams(1967) said that seed weight and the temperature during seed germination are very strongly related to one another.
According to Lovell and Moore (1970), larger seeds emerged slightly sooner than those of smaller seeds. But Naylor (1980) found no relation between seed size and emergence time in *Lolium perenne*, and also Maun and Cavers (1971) said that time of emergence may not be related to seed size or smaller seeds may actually germinate first.

SEED SIZE RELATED WITH GROWTH RATE, SEEDLING LEAF AREA AND NUMBER, AND HEIGHT.

Seed size affects on the root system:

Western Australian Sandalwood is well adapted to drought conditions (Loneragan 1990)
These plants exposed to the risk of drought, root system developed faster and longer and they tend to have heavier and larger seeds (Baker 1972)
Wulff (1986) discovered that seedlings from larger seeds produce longer roots than those from smaller seeds, and are able to emerge from greater depth of soil.

According to Schimpf (1977), larger seeds are associated with drier environments, probably due to their capacity to establish seedlings from deeper soil horizons, where moisture is more reliable. Where moisture is reliable nearer the soil surface, smaller seeds can successfully establish the next generation. These conditions imply natural selection acts on seed size during germination and emergence.

Seed size effects on the leaf system:

Salisbury (1942) concluded heavier seeds provide a larger provision of food reserve for the seedling, enabling it to establish its leaf system quickly (or above surrounding plants), thereby allowing photosynthesis to proceed as soon as possible. In addition, Maun and Cavers (1971) showed that the heavier seeds of untreated plants produced more vigorous seedlings with larger leaves and longer hypocotyls than did the lighter seeds of defoliated plants.

The above theories are supported by Waller (1985). He mentioned that cotyledon area strongly depended on seed weight, and, to a lesser extent, germination date. This study revealed that seed weight enhanced performance primarily through its effects on emergence date and cotyledon area.

Finally we can note that heavy seeds in a number of crop plant species, show that larger seeds produce faster root and shoot growth in the seedlings.

Seed size affects on the growth rate:

The growth rate of seedling shoots is proportional to the amount of stored food material in the seed (Baker 1972)

Mulff (1986) concluded seed size is positively correlated with cotyledon area and weight, leaf area, root weight and overall seedling dry weight. Waller (1985) supported this idea, he got a result that larger seeds also produce larger seedlings, which were more successful in growing to a larger final size.

On the other hand, Wulff (1986) gave the opposite idea, suggesting that the assumed positive correlation between seed and seedling size, do not always seem to hold. Melzack and Watts (1982) found no correlation between seed size and seedling dry weight.

Wulff (1986) indicated that seed size may only affect seedling survival if it affects both emergence ability and final seedling size.

Comparison smaller seeds and larger seeds affect to the growth rate:

Plants derived from smaller seeds are noticeably smaller than those from larger seeds even after two months of growth, but the differences no longer show at the time of flowering (Baker 1972)
Cideciyan and Malloch (1982) confirmed this point, they found that whatever disadvantage lighter seeds might have in the very early stage of growth, in the absence of intraspecific competition, small seed size appears to confer no disadvantage in later stages of growth.

In comparisons among species, large seeds have been associated with both enhanced growth and survivorship. (Waller 1985)
Moreover McWilliams et al.(1968) suggested that larger seeds may give rise to plants able to complete their life cycle in a shorter growing season.

Cideciyan and Malloch (1982) observed death of a significantly larger number of seedlings derived from small seeds than of seedlings from large seeds. They also hypothesed that plants derived from lighter seeds would not grow as well as plants derived from heavier seeds because the light seeds start with initially smaller resources.

Black (1957) discovered that deaths caused by self-thinning in populations of mixed seed size was almost exclusively confined to those plants derived from small seeds.

For the above reasons it can be suggested that seedling size is correlated with seedling survival-smaller seedlings having higher chance of mortality than larger ones (Wulff 1986)

SEED EXPERIMENTAL PROCEDURES

Green house studies reduce environmental variance, they can demonstrate the potential importance of genetic factors more reliably than can field studies (Waller 1985)

Therefore it can be seen that many respected scientists hold to the idea that larger seed size will produce stronger and faster growing individuals in a population than will the smaller ones. While others disagree with this idea. Through my investigation I hope to discover whether the earlier or the latter is true.

MATERIALS AND METHODS

MATERIALS:

- Trays
- Pots
- Oven- 60 degrees
- Brown paper bays (for dry weight).
- Rular
- Recording sheets (for growth rate and dry weight).
- Fungiside - Benlate
- Seedlings of *S.spicatum* (90)
- 25 nuts of *S.spicatum*
- Electric Weighing Scales
- Camera
- Buckets
- Nut Cracker

DESIGN OF THE EXPERIMENT:

Seed dimension and mass data of *S.spicatum* were given.

Dry weight of Kernel and Shell:
Twenty five nuts of *S.spicatum* were given, these seeds were weighted then cracked with keeping the kernel as intact as possible. Kernel (including any broken off bits) and all the shell pieces were weighted. The kernel and the shell were dried separately (brown bags) at 60 C for 2 - 4 days. They were reweighed and heated again until a constant weight was obtained.

Growth rate:
Ninety seedlings of *S.spicatum* were given. Each seedling was measured weekly, started on 25/07/94 according to categories on the recording sheet. Height of seedlings, leaf numbers and seeds were observed. If attached to the leaflet or not and if it is attached had the kernel been used up or not. State of emergence was also drawn.

Harvesting of the plant:
Three harvests, each of 25 plants, were made on

1st August
5th September
17th October

The healthy seedlings were chosen and carefully identified before each harvest. This was to ensure plants from each seed size/germinant age were represented at each harvest. The 25 bags were prepared for each roots, shoots and kernels.

Each bags were weighted. Root length and shoot length were measured after the plant was carefully removed from the pot within the water which avoided damaging the root systems.

These roots and shoots were put into the bags separately. Each fresh weight of roots, shoots and kernels were recorded by using an electric weighing scale. These bags were kept at 60 degrees for 2 - 4 days until constant weights were obtained.

MAINTENANCE:

Healthy seedlings were maintained by weekly observation. The plants were watered twice a week. Any fungal problem was removed by using Fungicide (Benlate).

ANALYSIS THE DATA:

For seed dimention/mass:
The sets of seed dimention and mass data are analyzed by a computer. The mean values and variations are calculated by Minitab.
To find out the significant difference in seed mass, dimension and length of seed within a species. The data will be tested by using a ONE WAY ANOVA.
By using the results from nuts dry weights, we can analyze the relationship between food materials in the seed and seed mass.
Any relationship between seed size/mass and food material inside the seed can be detected.

For seed size/mass and germination:
SPEARMAN RANK CORRELATION COFFICIENT will be used to analyze the seed size/mass, and the affects to start of germination, rate of germination and final germination percentage. The germination day of each seeds was already given.

For seed size/mass and growth rate:
The data from weekly observation, the growth rate of seedlings is taken. Each harvests data was used to obtain actual growth rate of the plants. Each dry weight of roots, shoots, kernels were compared with previous results and carried out the actural growth rate. A REGRESSION TEST will be carried out to detect any correlation between seedmass/size and growth rate, seedling leaf number and height.

RESULTS:

For seed dimension/mass:

Fig 1 shows ANOVA analyses of fruit dimension, there is no significant difference in the dimension of the fruit within a species.
However Fig 2 ANOVA for the Fruits mass has a significant difference in mass, within a species.

The relationship between the total fruit weight and the Kernels weighed (wet) are indicated in Fig 3 and Fig 4. 25 fruits were used for this analysis. The analysis showed there is a strong linear relationship (68.9 %) between the total fruit weight and Kernel weight.
The graph (Fig 5) also supports this strong positive linear relationship.
In addition, there is a strong linear relationship between the total fruit weight and the shell weight (81.4 %). They have strong positive relationship same as the kernel weight.

For seed size/mass and Germination:

Correlation between the fruits diameter/mass and the germination days were analysed by using Spearman Rank Correlation Coefficient (Fig 8).
The results show there is no correlation between the fruit diameter and the germination dates in the seeds, as well as the relationship between the fruits mass and the germination rate. (and numbers?)

For seed size/mass and growth rate:

Fig 9 and Fig 10 show the regression test for the fruit dimension and growth rate of stems (mm) and Leaves (number). The results show there is a weak linear relationship between them.
Fig 11 and Fig 12 describe the relationship between the fruit diameter and the growth rate of the stems/leaves by dot plot. The linear relationship is hard to see in these plots.

Regression tests for the fruit mass and growth rate of stems/leaves is in Fig 13 and Fig 15. Both tests show no linear relationship between them (see Fig 14 and Fig 16).

However between fruits diameter 18.0 - 19.2 mm shows higher growth rate of stems/leaves compared with the other.
In the fruits mass 2.40 -3.00 g have higher growth rate of stems/leaves.

Table 2 shows the percentage of seedlings in the trials, kernels used up and seeds released. The results indicate eight weeks after the germination, the kernels start to be used up. 14 - 15 weeks after the germination, half of seedlings had used up their kernels.

Few seeds were released from the seedlings even though that had not been used up in the first few weeks. Nearly 40 % of the seeds were released 14 -15 weeks after germination.
In 15 weeks after the germination, 62.50 % of seedlings used up the kernels and 37.50 % of seedlings released the seeds. It demonstrates that after seedlings had used up their kernels they kept their leaves inside.

Fig 17 and Fig 18 show the growth rate of a stem with kernels. The seedling Plot No 59 used up the kernel at 12 weeks after the germination. The kernels were used up 8 weeks after their germination in the seedlings Plot No 61 and Plot No 62.

The Graph (Fig 17) shows that the growth rate decreased a few days after the kernel was used up, but 4-5 weeks after that the plant gradually recovered.
In the Fig 18 also shows that the leaf numbers had decreased a few weeks after their kernels were used up. Then the leaf numbers, started to increase at 13-14 weeks after germination.

Growth rate in each Harvests:

Table 2 and Fig 17 show difference in mean dry weight at each harvest. The mean dry weight of Roots, Shoots and Kernels were taken 30, 65 and 72 days after germination.
The increasing mean of dry weight of Roots and Shoots are shown in the graph (Fig 17).
On the other hand, the mean dry weight of Kernels decreased at each Harvest.
Fig 20 represents the growth rate of the average dry plant mass and the dry kernels mass. It shows the increase of the average plant mass that caused the decrease of the average kernels mass.

The number of haustorias had increased greatly 65 days after the germination. However the next harvest time (112 days after the germination) showed a slight increase in the number of haustoria.

Plate 1 indicates two different seedlings, Plate 1.1 is smaller than Plate 1.2. The size of seeds of Plate 1.2 was larger than Plate 1.1, also its germination day was faster than Plate 1.1.

Plate 2 shows the presence of haustoria in the rooting system.
Plate 3 to Plate 5 presents the variation of S.spicatum seedlings, three different types of seedlings were detected.

Fig 1: ANOVA for the fruits dimension

```
MTB > Describe c1-c6

                N      MEAN    MEDIAN    TRMEAN     STDEV    SEMEAN
C1             40    18.735    18.825    18.794     1.549     0.245
C2             40    18.546    18.505    18.599     1.347     0.213
C3             40    18.191    18.260    18.181     1.470     0.232
C4             40    18.413    18.560    18.441     1.116     0.176
C5             40    18.028    18.180    18.065     1.572     0.249
C6             40    18.165    18.080    18.151     1.134     0.179

              MIN       MAX        Q1        Q3
C1         14.850    21.190    18.020    19.823
C2         15.360    20.660    17.730    19.692
C3         14.710    21.480    16.905    19.355
C4         15.250    20.580    17.497    19.273
C5         13.510    21.750    16.943    18.733
C6         15.790    21.060    17.523    18.995

MTB > Aovo c1-c6

ANALYSIS OF VARIANCE
SOURCE     DF        SS         MS         F        p
FACTOR      5     14.14       2.83      1.49    0.193
ERROR     234    443.68       1.90
TOTAL     239    457.82
                                        INDIVIDUAL 95 PCT CI'S FOR MEAN
                                        BASED ON POOLED STDEV
 LEVEL      N      MEAN      STDEV   ---------+---------+---------+-------
C1         40    18.735      1.549                     (--------*-------)
C2         40    18.546      1.347                 (--------*--------)
C3         40    18.191      1.470        (--------*-------)
C4         40    18.413      1.116                (-------*--------)
C5         40    18.028      1.572     (--------*-------)
C6         40    18.165      1.134        (-------*--------)
                                     ---------+---------+---------+-------
POOLED STDEV =    1.377                  18.00     18.50     19.00
```

No hypothesis : There is no significant difference in the fruits dimension within a species

Hypothesis : There is significant difference in the fruits dimension within a speciee.

From the result, P = 0.193 is bigger than P = 0.05 therefore reject hypotheeis (α = 0.05). The means are similar and don't have significant difference within aspeciee.

Fig 2 : ANOVA for the fruits mass

MTB > Describe c1-c6

	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
C1	40	2.970	2.969	2.970	0.655	0.104
C2	40	2.9010	2.7459	2.8940	0.5734	0.0907
C3	40	2.693	2.729	2.691	0.641	0.101
C4	40	2.8249	2.7705	2.8344	0.4782	0.0756
C5	40	2.7281	2.7933	2.7385	0.6065	0.0959
C6	40	2.5893	2.6374	2.5751	0.4664	0.0737

	MIN	MAX	Q1	Q3
C1	1.689	4.381	2.532	3.573
C2	1.7994	4.1250	2.5373	3.3029
C3	1.484	3.948	2.187	3.078
C4	1.7344	3.8035	2.4679	3.2386
C5	1.1365	4.0331	2.4169	3.0150
C6	1.6860	3.7603	2.2559	2.8073

MTB > aovo c1-c6

ANALYSIS OF VARIANCE

SOURCE	DF	SS	MS	F	p
FACTOR	5	3.975	0.795	2.41	0.038
ERROR	234	77.332	0.330		
TOTAL	239	81.307			

```
                                     INDIVIDUAL 95 PCT CI'S FOR MEAN
                                     BASED ON POOLED STDEV
LEVEL     N      MEAN     STDEV   ---------+---------+---------+------
C1       40    2.9702    0.6553                       (--------*-------)
C2       40    2.9010    0.5734                   (---------*--------)
C3       40    2.6928    0.6408          (--------*--------)
C4       40    2.8249    0.4782               (---------*--------)
C5       40    2.7281    0.6065           (--------*--------)
C6       40    2.5893    0.4664     (-------*--------)
                                  ---------+---------+---------+------
POOLED STDEV =   0.5749                  2.60      2.80      3.00
```

MTB > Note: ANOVA for the Mass of the Fruits

MTB >

No Hypothesis : There is no significant difference in the fruits mass within a species

Hypothesis : There is significant difference in the fruits mass within a species.

From the result, P = 0.038 is smaller than P = 0.05. therefore reject No Hypothesis, accept Hypothesis. The means are not similar and The seed mass has rang 2.5g - 3.0g.

Table 1: Total Fruits Mass with Kernels and Shell Mass

Mass (g)	Total. Fruits Mass	Wet Kernel Mass	Wet Shell Mass	Dry Kernel Mass	Dry Shell Mass
1	1.84	0.35	1.48	0.34	1.36
2	2.30	0.69	1.60	0.67	1.47
3	2.10	0.60	1.49	0.52	1.40
4	2.81	0.78	2.02	0.75	1.86
5	2.95	1.09	1.84	1.07	1.71
6	2.83	0.82	2.01	0.79	1.87
7	2.39	0.82	1.57	0.79	1.45
8	2.86	0.42	2.44	0.41	2.23
9	3.75	0.95	2.80	0.92	2.56
10	1.90	0.38	1.52	0.36	1.39
11	2.60	0.97	1.63	0.94	1.52
12	2.17	0.59	1.55	0.57	1.45
13	2.27	0.71	1.54	0.69	1.41
14	1.67	0.50	1.17	0.48	1.07
15	1.91	0.66	1.24	0.64	1.13
16	3.03	1.14	1.88	1.11	1.76
17	1.61	0.48	1.13	0.47	1.05
18	1.29	0.08	1.21	0.07	1.10
19	2.81	1.09	1.72	1.06	1.59
20	3.51	1.43	2.08	1.38	1.90
21	2.39	0.62	1.77	0.06	1.62
22	2.68	0.91	1.77	0.88	1.64
23	3.06	1.04	2.02	1.00	1.86
24	2.13	0.66	1.46	0.64	1.36
25	1.87	0.46	1.18	0.45	1.11
Means	2.43	0.73	1.68	0.70	1.55

Fig 3: regression for Total fruits weight and kernels weight (wet)

MTB > regression c1 1 c2

The regression equation is
TotF = 1.22 + 1.65 Wkern

Predictor	Coef	Stdev	t-ratio	p
Constant	1.2222	0.1826	6.69	0.000
Wkern	1.6524	0.2317	7.13	0.000

s = 0.3440   R-sq = 68.9%   R-sq(adj) = 67.5%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	6.0155	6.0155	50.84	0.000
Error	23	2.7215	0.1183		
Total	24	8.7369			

Unusual Observations

Obs.	Wkern	TotF	Fit	Stdev.Fit	Residual	St.Resid
8	0.42	2.8600	1.9162	0.0995	0.9438	2.87R
9	0.95	3.7500	2.7919	0.0856	0.9581	2.88R
20	1.43	3.5100	3.5851	0.1762	-0.0751	-0.25 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regression c1 1 c3

The regression equation is
TotF = 0.136 + 1.36 Wshel

Predictor	Coef	Stdev	t-ratio	p
Constant	0.1363	0.2346	0.58	0.567
Wshel	1.3601	0.1356	10.03	0.000

s = 0.2658   R-sq = 81.4%   R-sq(adj) = 80.6%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	7.1120	7.1120	100.66	0.000
Error	23	1.6250	0.0707		
Total	24	8.7369			

Unusual Observations

Obs.	Wshel	TotF	Fit	Stdev.Fit	Residual	St.Resid
8	2.44	2.8600	3.4550	0.1153	-0.5950	-2.48R
9	2.80	3.7500	3.9447	0.1602	-0.1947	-0.92 X
20	2.08	3.5100	2.9654	0.0754	0.5446	2.14R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

Fig 4: regression for total fruits weight and shell weight (wet)

From the result of Fig 3 : regression for the fruits total weight and kernels weight (wet).

No.Hypothesis: There is no linear relationship between the fruit total weight and kernels weight

Hypothesis: There is linear relationship between the fruit total weight and kernels weight.

When $P < 0.05$
Tcal = 7.13
Tcritical = 2.069

The result shows accept Hypothesis, there is linear relationship between the total weight and kernels weight.

From the result of Fig.4 regression for total fruits weight and shell weight (wet).

No.Hypothesis: There is no linear relationship between the total fruits weight and shell weight.

Hypothesis: There is linear relationship between the total fruit weight and shell weight.

When $P < 0.05$
Tcal = 10.03
Tcritical = 2.069

From the result, the hypothesis that there is linear relationship between the total fruit weight and shell weight (wet) is accepted.

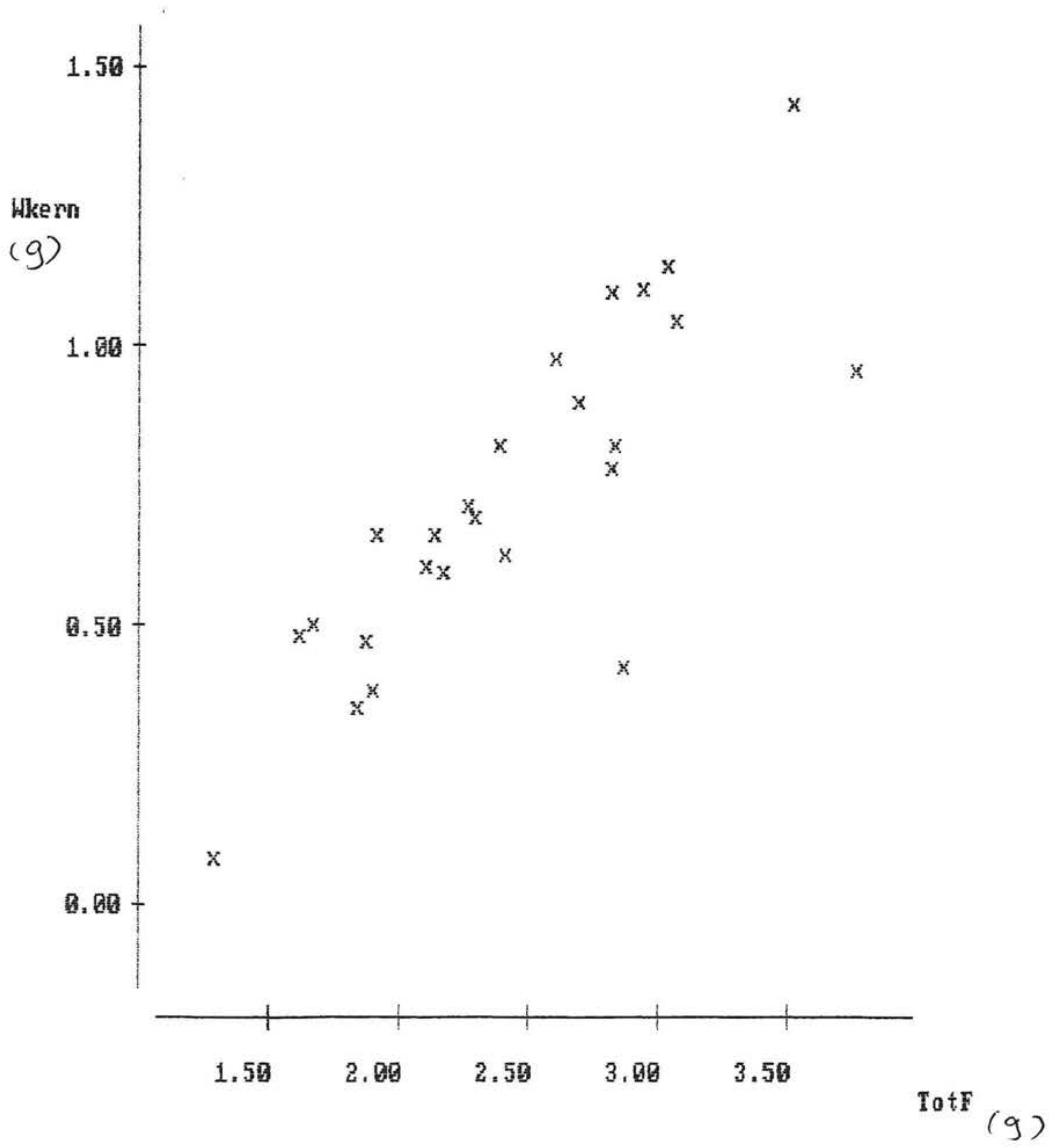

Fig 5 : Graph of Total fruits weights and Kernels weight (wet)

Fig 8 : Correlation between the fruits diameter/mass and Germination days in the seeds.

```
MTB > info c1 c2 c3 c4 c5  c7 c8 c9

COLUMN     NAME       COUNT
C1         Diameter      90
C2         Mass          90
C3         Germi/Da      90
C4         R/Stem         1
C5         R/Leaf         0
C7         Rank C1       90
C8         Rank C2       90
C9         Rank C3       90

MTB > correlate c7 c9

Correlation of C7 and C9 = 0.025

MTB > correlate c8 c9

Correlation of C8 and C9 = 0.007

MTB > c7 is Rank of c1(Fruits diameter), c8 is Rank of c2(Fruits mass) and c9 i
    > s Rank of c3(Germination day after transplanted) is Rank of
* ERROR * Name not found in dictionary
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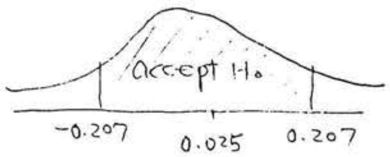
• Correlation of Fruits diameter and Germination days of seeds.

$r_s = 0.025$

$r_{critical}$ [N = 90] = 0.207 ($\alpha = 0.05$)



H₀ = no correlation between the fruits diameter and germination da

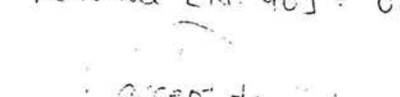
H_A = correlation between the fruit diameter and germination d

From the result, no correlation between the fruits diameter and germination dates in the seeds

• Correlation of fruits mass and Germination days of seeds

$r_s = 0.007$

$r_{critical}$ [N = 90] = 0.207 ($\alpha = 0.05$)



H₀ = no correlation between the fruits mass and germination days

H_A correlation between the fruits mass and germination days

The result shows there is no correlation between the fruits mass and germination days in the seeds

Fig 9 (Top): regression of Fruits dimension and Growth rate of stem. (mm)

```
MTB > regress c1 1 c4

The regression equation is
Diameter = 17.8 + 0.0529 R/Stem

Predictor        Coef        Stdev     t-ratio        p
Constant      17.8156       0.2008       88.72    0.000
R/Stem        0.05285      0.03105        1.70    0.092

s = 1.319       R-sq = 3.2%      R-sq(adj) = 2.1%

Analysis of Variance

SOURCE         DF          SS           MS         F         p
Regression      1       5.038        5.038      2.90     0.092
Error          88     153.071        1.739
Total          89     158.109

Unusual Observations
Obs.  R/Stem  Diameter        Fit Stdev.Fit  Residual    St.Resid
  6     16.0    19.280     18.661     0.378     0.619      0.49 X
  8      3.0    14.900     17.974     0.148    -3.074     -2.35R
 11     18.0    20.620     18.767     0.437     1.853      1.49 X
 16     19.0    18.790     18.820     0.466    -0.030     -0.02 X
 42     14.8    18.150     18.598     0.344    -0.448     -0.35 X
 53      0.5    20.580     17.842     0.190     2.738      2.10R
 61      1.4    14.490     17.888     0.173    -3.398     -2.60R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

MTB > regress c1 1 c5

The regression equation is
Diameter = 17.8 + 0.127 R/Leaf

Predictor        Coef        Stdev     t-ratio        p
Constant      17.8411       0.2341       76.21    0.000
R/Leaf         0.1267       0.1074        1.18    0.241

s = 1.330       R-sq = 1.6%      R-sq(adj) = 0.4%

Analysis of Variance

SOURCE         DF          SS           MS         F         p
Regression      1       2.460        2.460      1.39     0.241
Error          88     155.649        1.769
Total          89     158.109

Unusual Observations
Obs.  R/Leaf  Diameter        Fit Stdev.Fit  Residual    St.Resid
  8     2.00    14.900     18.094     0.143    -3.194     -2.42R
 11     0.00    20.620     17.841     0.234     2.779      2.12R
 25     6.00    18.040     18.601     0.478    -0.561     -0.45 X
 32     6.00    18.290     18.601     0.478    -0.311     -0.25 X
 33     4.70    19.600     18.436     0.347     1.164      0.91 X
 53     0.02    20.580     17.844     0.232     2.736      2.09R
 61     1.30    14.490     18.006     0.148    -3.516     -2.66R
```

Fig 10 (below): regression of fruits dimension and Growth rate of Leaves (n)

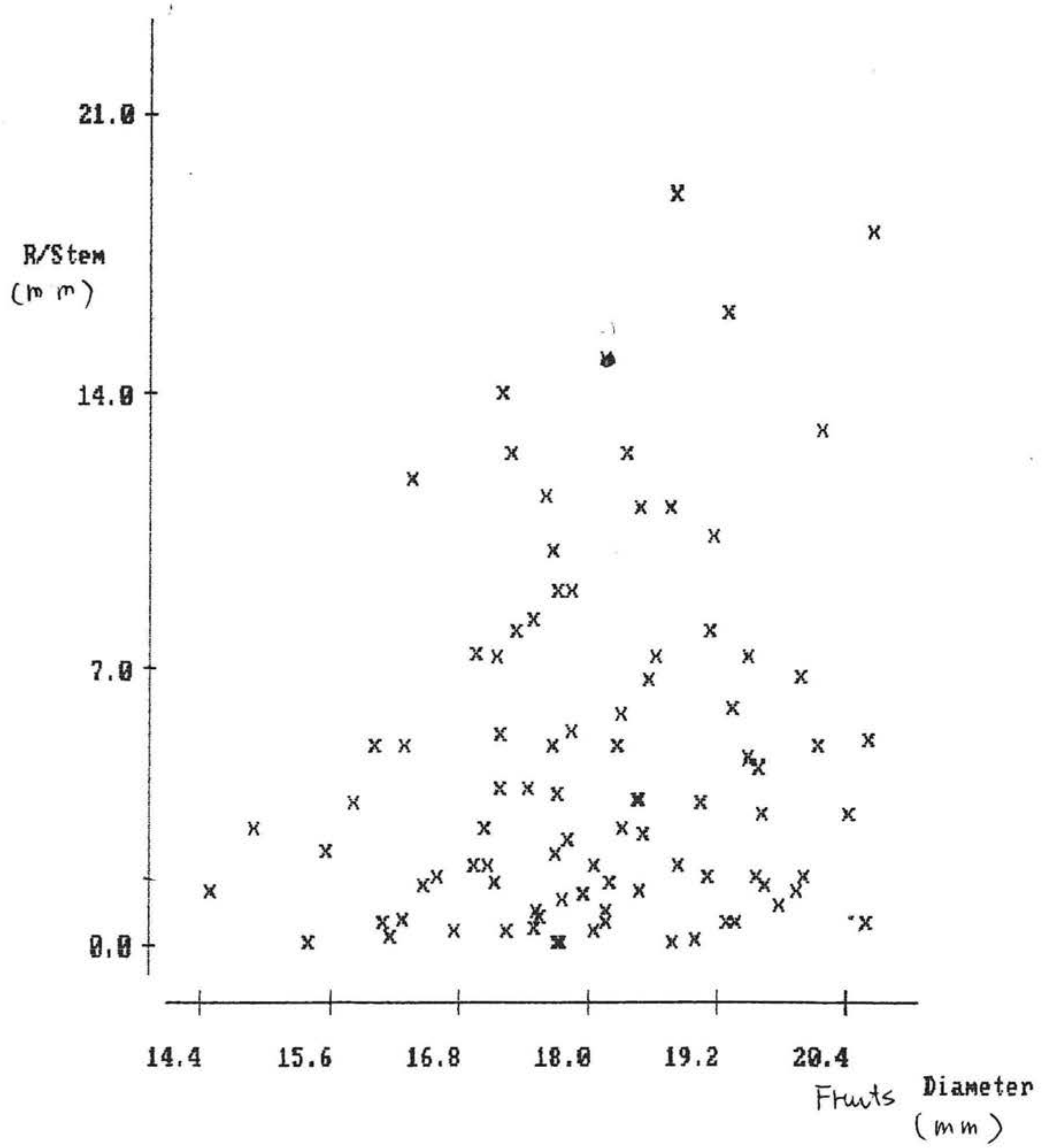


Fig 11 : Graph of Fruits diameter (mm) and Growth rate of Stem (mm)

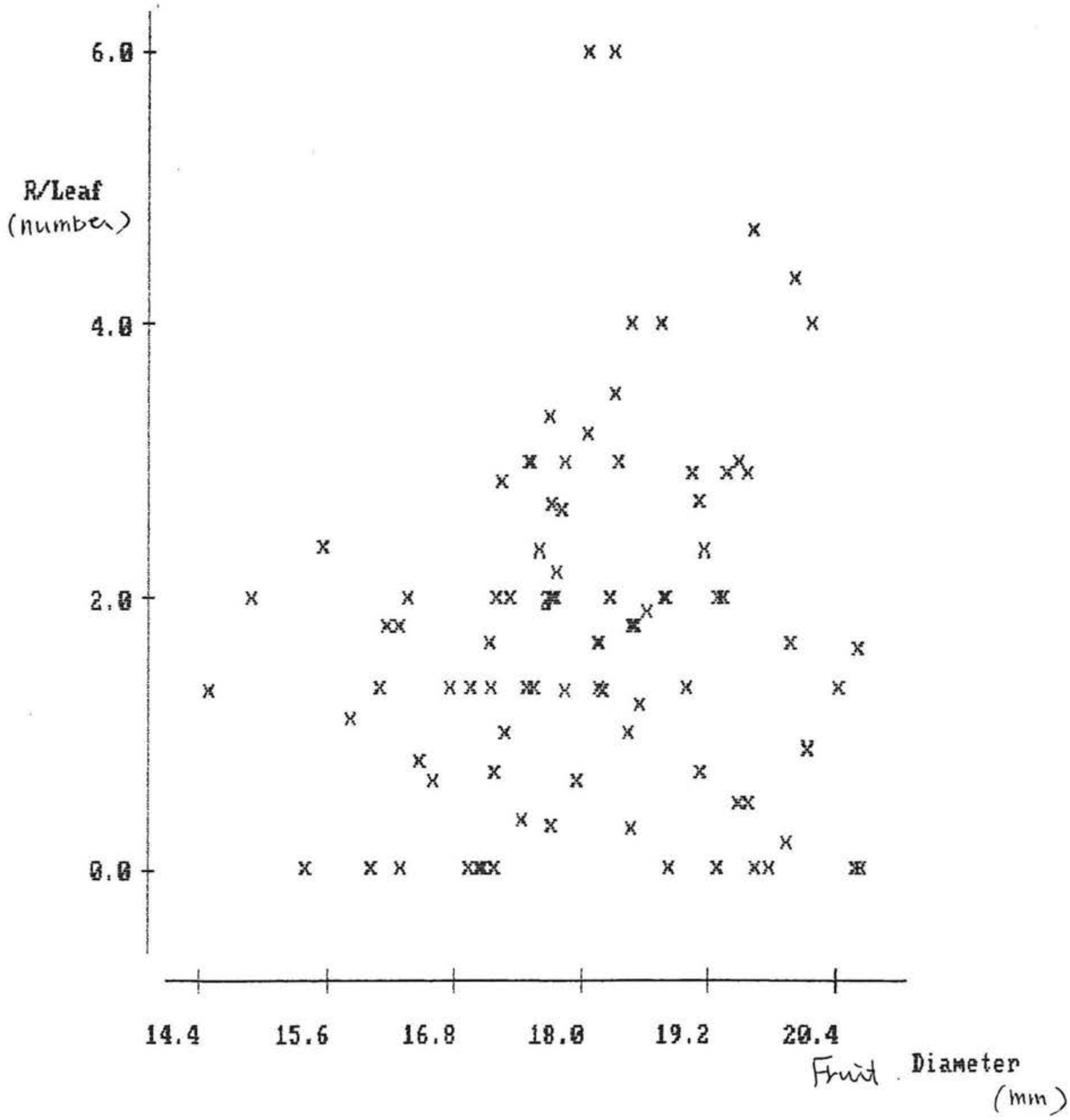


Fig 12: Graph of fruit diameter (mm) and Growth rate of Leaves (number

Fig 13: Regression for the fruits mass and growth rate of Ste[m]

```
MTB > regress c2 1 c4

The regression equation is
Mass = 2.64 + 0.0217 R/Stem

Predictor       Coef        Stdev     t-ratio        p
Constant     2.63986      0.08003       32.98    0.000
R/Stem       0.02174      0.01238        1.76   [0.083]

s = 0.5257       R-sq = 3.4%       R-sq(adj) = 2.3%

Analysis of Variance

SOURCE        DF          SS          MS         F        p
Regression     1      0.8523      0.8523      3.08    0.083
Error         88     24.3169      0.2763
Total         89     25.1692

Unusual Observations
Obs.  R/Stem       Mass        Fit Stdev.Fit  Residual    St.Resid
  3      1.0     3.8058     2.6616    0.0716    1.1442       2.20R
  6     16.0     3.0061     2.9876    0.1508    0.0185       0.04 X
 11     18.0     3.8627     3.0311    0.1741    0.8316       1.68 X
 16     19.0     3.3843     3.0529    0.1859    0.3314       0.67 X
 42     14.8     2.8111     2.9616    0.1371   -0.1505      -0.30 X
 53      0.5     4.0490     2.6507    0.0757    1.3983       2.69R
 60      5.2     4.3927     2.7525    0.0558    1.6402       3.14R
 61      1.4     1.4937     2.6694    0.0689   -1.1757      -2.26R
 79      1.7     3.7983     2.6768    0.0665    1.1215       2.15R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.
```

Note: C2 = Fruits mass   C4 = G.Rate of Stem

SUBC> Symbol 'x'.

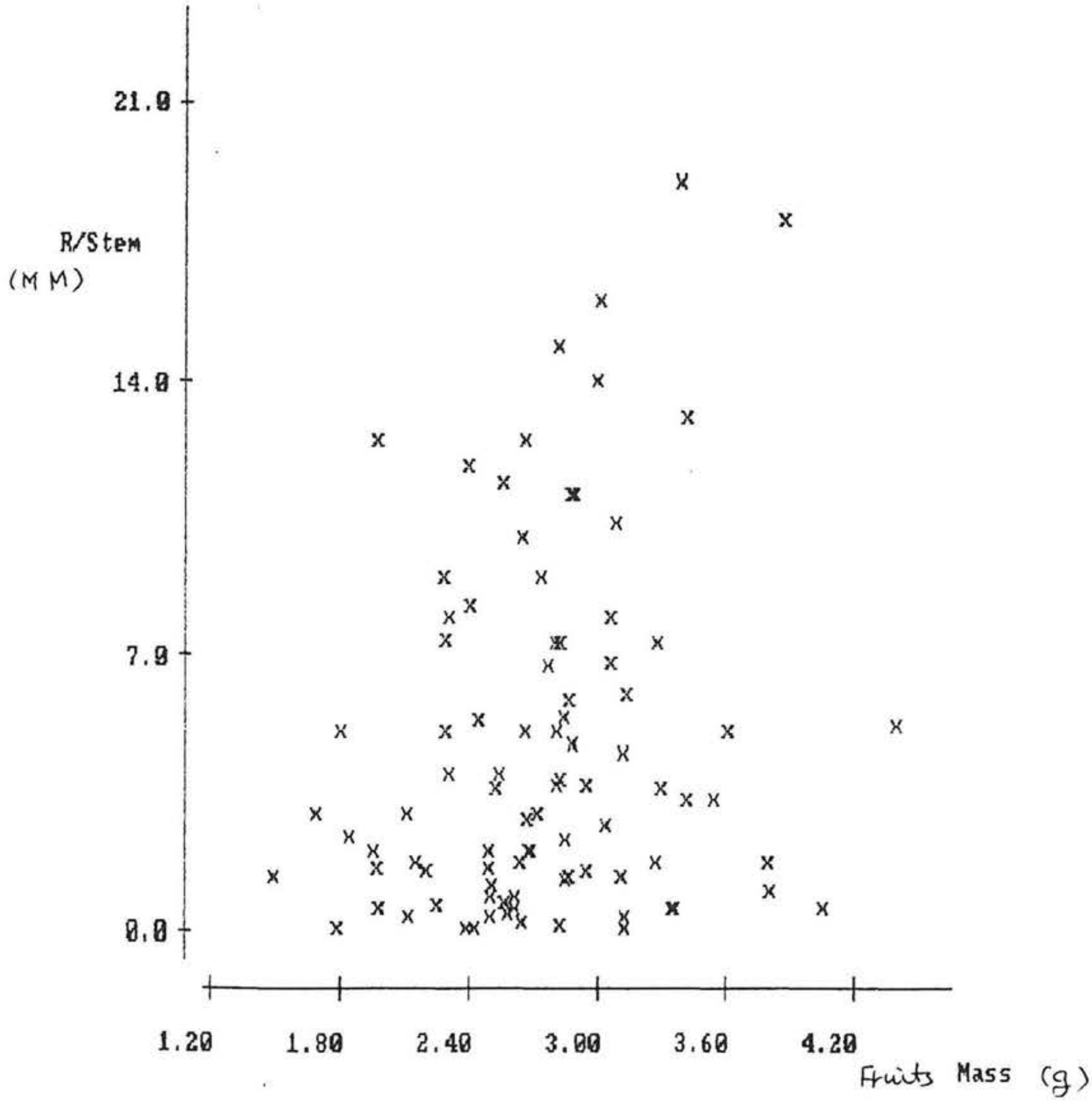


Fig14: Graph of the fruits mass and Growth rate of stem (mm)

Fig 15 : Regression for the fruits mass and growth rate of Leaf

```
MTB > regress c2 1 c5

The regression equation is
Mass = 2.64 + 0.0605 R/Leaf

Predictor        Coef        Stdev     t-ratio        p
Constant      2.63561      0.09309       28.31    0.000
R/Leaf        0.06052      0.04271        1.42    0.160

s = 0.5288      R-sq = 2.2%      R-sq(adj) = 1.1%

Analysis of Variance

SOURCE        DF         SS          MS         F        p
Regression     1     0.5616      0.5616      2.01    0.160
Error         88    24.6075      0.2796
Total         89    25.1692

Unusual Observations
Obs.  R/Leaf      Mass       Fit  Stdev.Fit  Residual    St.Resid
  3     0.00    3.8058    2.6356     0.0931    1.1702       2.25R
  8     2.00    1.6894    2.7567     0.0568   -1.0673      -2.03R
 11     0.00    3.8627    2.6356     0.0931    1.2271       2.36R
 25     6.00    2.6738    2.9988     0.1900   -0.3250      -0.66 X
 32     6.00    2.8585    2.9988     0.1900   -0.1403      -0.28 X
 33     4.70    3.4099    2.9201     0.1379    0.4898       0.96 X
 53     0.02    4.0490    2.6368     0.0924    1.4122       2.71R
 60     1.64    4.3927    2.7349     0.0559    1.6578       3.15R
 61     1.30    1.4937    2.7143     0.0589   -1.2206      -2.32R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.
```

Note : C2 = Fruits mass   C4 = Growth rate of Leaf

SUBC>   Symbol 'x'.

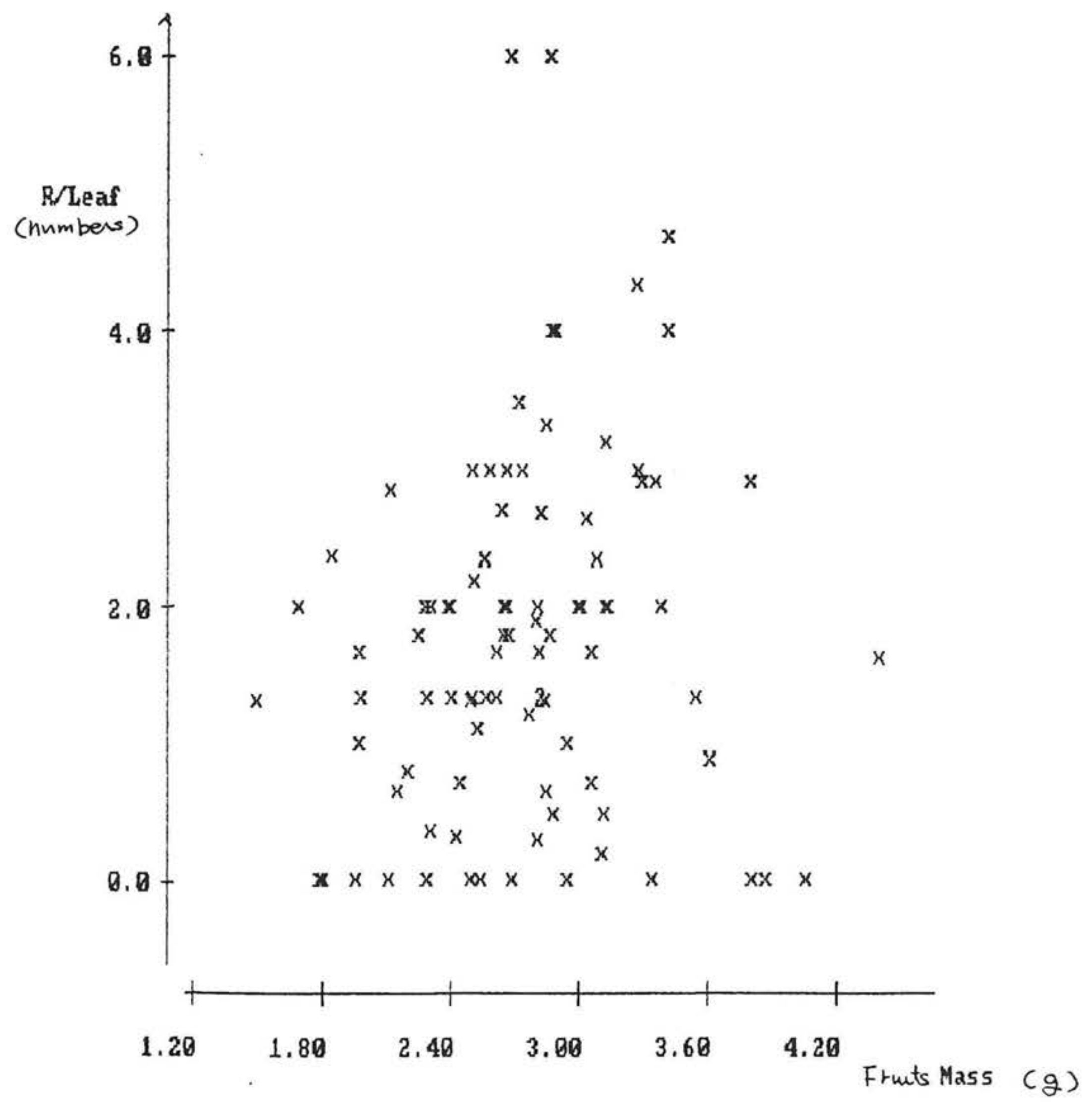


Fig 16: Graph of the fruits mass and Growth rate of Leaves. (n)

Table 2 : Percentage of Seedlings in the trials, Kernels used up and Seeds released.

Weeks after Germination	Percentage of seedlings, kernels used up (%)	Percentage of seedlings, seeds released (%)
4	0	0
5	0	1.11
6	0	1.54
7	0	1.54
8	7.69	4.62
9	6.15	6.15
10	12.31	7.69
11	10.00	12.50
12	12.50	17.50
13	15.00	25.00
14	45.00	35.00
15	62.50	37.50

Fig 17. Relationship of Growth Rate
Stem length and Kernels

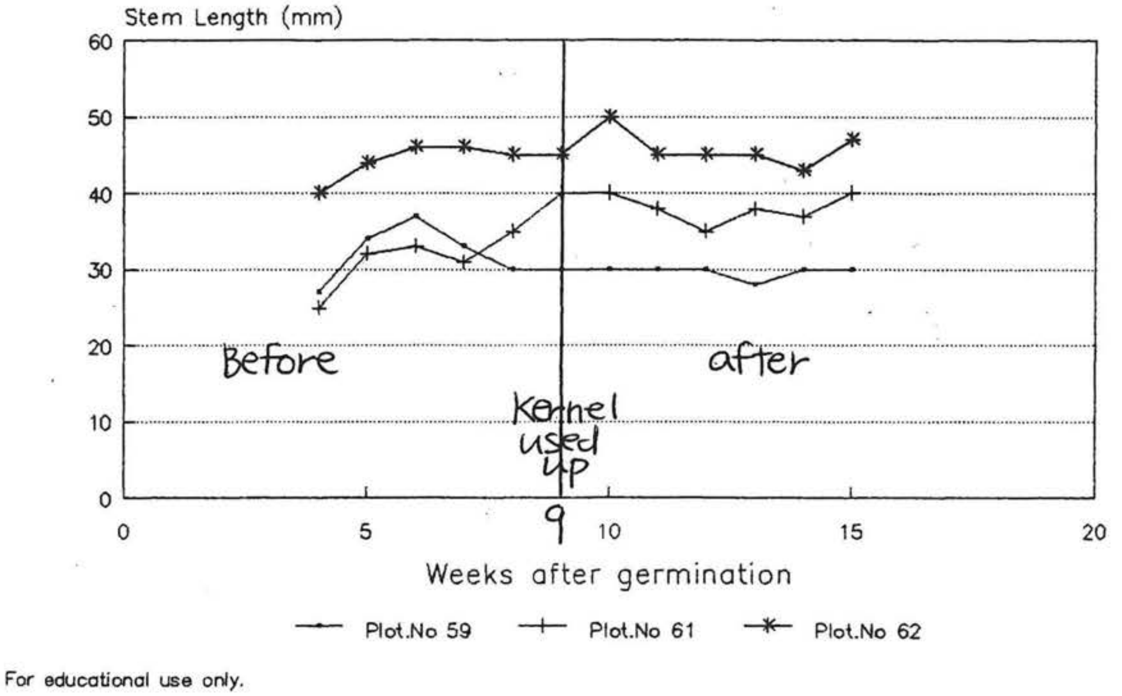


Fig 18. Relationship of Growth Rate
Leaf numbers and Kernels

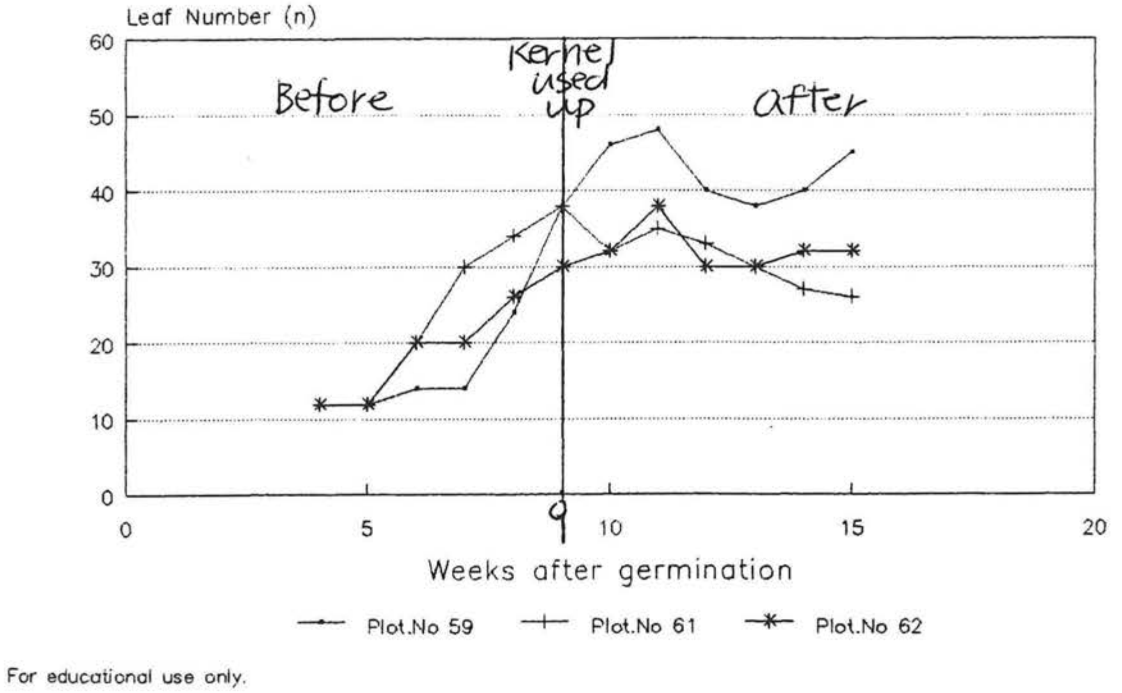


Fig 19

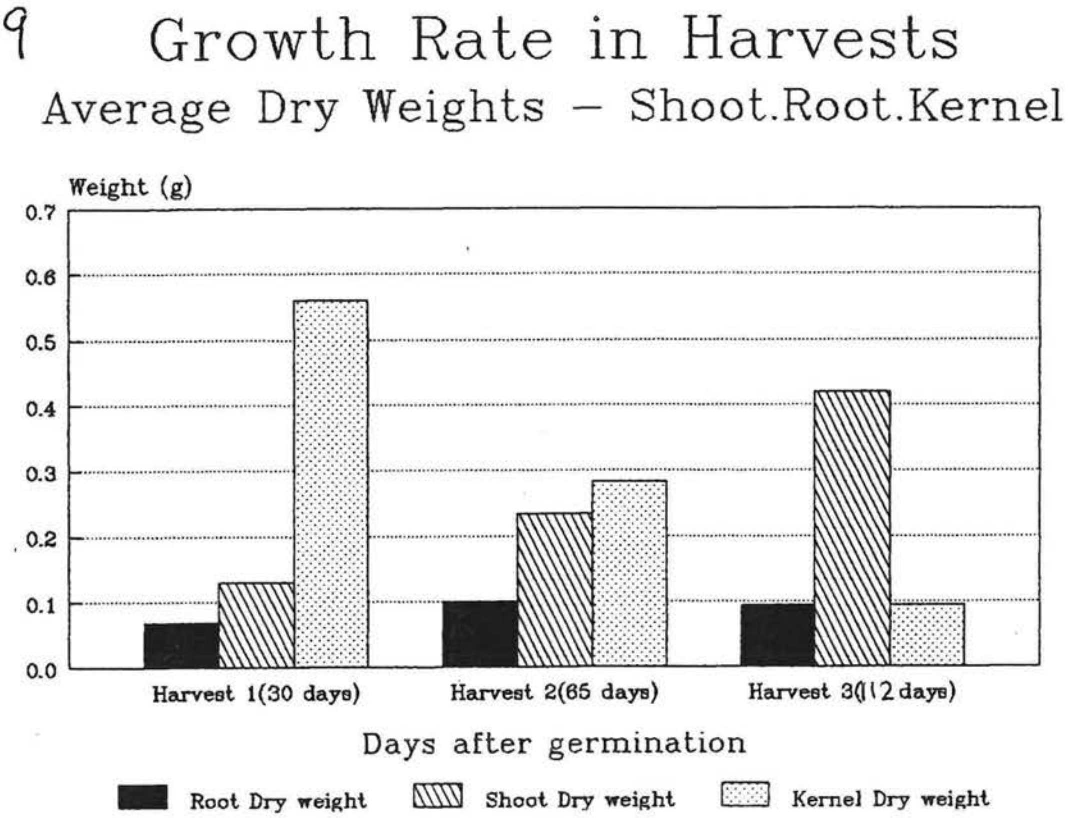
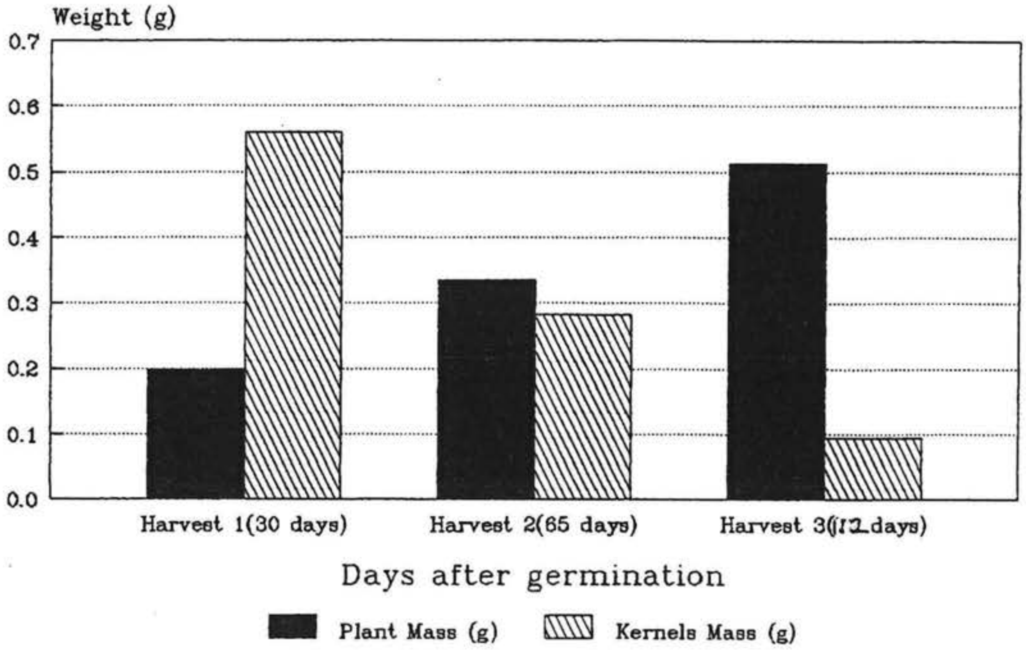


TABLE 3 : Average Dry Weight of Roots, Shoots and kernels in each Harvests - 30,65,and 72 days after germination.

	Root Dry Weight (g)	Shoot Dry Weight (g)	Kernel Dry Weight (g)
Harvest 1 (30 days)	0.0694	0.1290	0.5599
Harvest 2 (65 days)	0.100125	0.2341	0.2829
Harvest 3 (112 days)	0.09292	0.4197	0.0958

Fig 20. Growth Rate in Harvests

Average Dry Weights – Plant/Kernels Mass



For educational use only.

Table 4: Number of Haustoria in each Harvests.

	Number of haustoria (n)
Harvest 1 (30 days)	0
Harvest 2 (65 days)	28
Harvest 3 (112 days)	32

12/15

Plate 1.1

The seedling of S. spicatum developed from the seed: 17.13 mm in diameter 1.974 g in Mass

Plate 1.2

The seedling of S. spicatum developed from the seed: 17.43 mm in diameter 2.3054 g in Mass.

Plate 2. The haustria in the root system of S. spicatum size: 1.5 mm.

Variation of *Santalum spicatum* Seedlings
Harvest 65 days after germination

Plate 3: S. spicatum developed from The seed 17.5 mm in diameter 3.5 g in Mass

Plate 4: S. spicatum developed from the Seed 17.23 mm diameter 2.1759 g Mass

Plate 5: S. spicatum developed from the Seed
19.15 mm diameter
3.0795 g Mass

DISCUSSION:

For seed dimension/mass:

There is a significant difference in the seed mass within a species, but no difference in the size detected by an ANOVA. Agren (1989) and Janzen (1978) supported the idea that the seed may vary considerably within populations and within individual plants.
The differences in seed weights are due to the difference in the amount of food in the kernel.
The Fig.3 and Fig.4 show the increasing of total fruit mass causing the increase of kernel weights, as well as the mass of shell. Therefore it can be said that, the bigger the size the heavier the mass in *Santalum.spicatum.*
The seed of *S.spicatum* tend to have large/heavy seeds when compared with other *Santalum species.*
Schimpf (1977) comments that larger seeds are associated with drier environments, probably due to their capacity to establish seedlings from deeper soil horizons, where moisture is more reliable. Therefore the *S.spicatum* is perfectly suited to being tolerant under desert conditions.

For seed size/mass and germination:

The seed size/mass do not affect the time of germination. The test (Fig.8) shows there is no correlation between the fruits diameter/mass and the germination.
The germination is more effected by the environmental factors such as temperature, light intensity, moisture, and the chemical condition of the seeds.
Maun and Caver (1971) comment that the time of emergence may not be related to seed size.
In addition, germination is more closely related with the characteristic of the seeds when kept under the optimum conditions, it germinates faster.

For seed size/mass and growth rate:

The results show a weak linear relationship between the fruit size and growth rates (Fig 11 and Fig 12).
Moreover Fig 13 and Fig 15 demonstrate no linear relationship between the fruit mass and growth rate.

However, they have the optimum fruits diameter and mass to grow quickly.
Maun and Cavers (1971) shows that the heavier seeds produce more seedlings with larger leaves and longer hypocotyls than

do the lighter seeds.
However the seedlings have the optimum fruit diameter (18.0-19.2 mm) and mass (2.40 - 3.00 g) and higher growth rates of stem/leaves.
Melzack and Watts (1982) also found no correlation between seed size and seedling dry weight. Therefore they assumed that the hypothesis that position was correlated between seed and seedling size does not always seem to hold.

However sometimes the theory that the larger seed has a high growth rate fits some results, Plate 1.1 and Plate 1.2 shows a huge difference in the growth rate, Plate 1.2 developed from the larger seed and had a higher growth rate as well as a faster germination rate.

In Table 2, most of the seedlings used up the kernels 14 -15 weeks after germination. Some seedling kernels were still attached to the plants after 15 weeks.
The growth rate decreased after a few weeks and the kernels in which is food was stored were depleted. After this time they gradually recovered. This was due to the effects of photosynthesis and the plant producing its own food.
This system becomes effective after kernel is depleted (See Fig 17 and Fig 18).

The graph shows the higher growth rates tend to appear in the heavier seeds, but the lighter seeds also show a high survival rate and good growth.
Cideciyan and Mallock (1982) confirm this point, whatever disadvantage the lighter seeds might have in the early stage of growth, in the absence of intraspecific competition, small seed size appears to suggest no disadvantage in later stages of growth.

Growth rate in each Harvests:

According to the results of Fig 17, in each harvests the mean dry weight of roots and shoots increased, with the decrease in kernel weight. This proves that the kernels gave their food reserve to growth of the stem and the roots. The average mass of the kernel decreased by half of the previous mass in each harvest.

The highest amount of haustorias were produced 65 days after seedling germination. After 112 days there was no great increase in the production of haustorias. The haustorias can be seen on Plate 2.

On Plates 3, 4 and 5, we can see three different types of seedlings. This is due to their different genetic varieties. Plate 3 had two stems in the one rooting system, one seedling displays a smaller size than the other's.

CONCLUSION:

There is a significant difference in the fruit mass within a species, *Santalum spicatum,* but no difference in the size of the fruits.

No correlation between the fruit mass/diameter and germination was detected. The seed size/mass did not affect the time of germination, it affects the genetical characteristics in the seed more. Affects numbers which germinated?

The fruits size/mass do not affect the growth rate. They have a optimum size/mass to grow effectively.

By increasing the mass of the shoot/root causes the decreased of the kernel's mass. Because the kernels give the food resources to the plant growth.

Most of haustoria were produced in 65 days after the germination.

Good effort Tisha

11/15

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APPENDICS

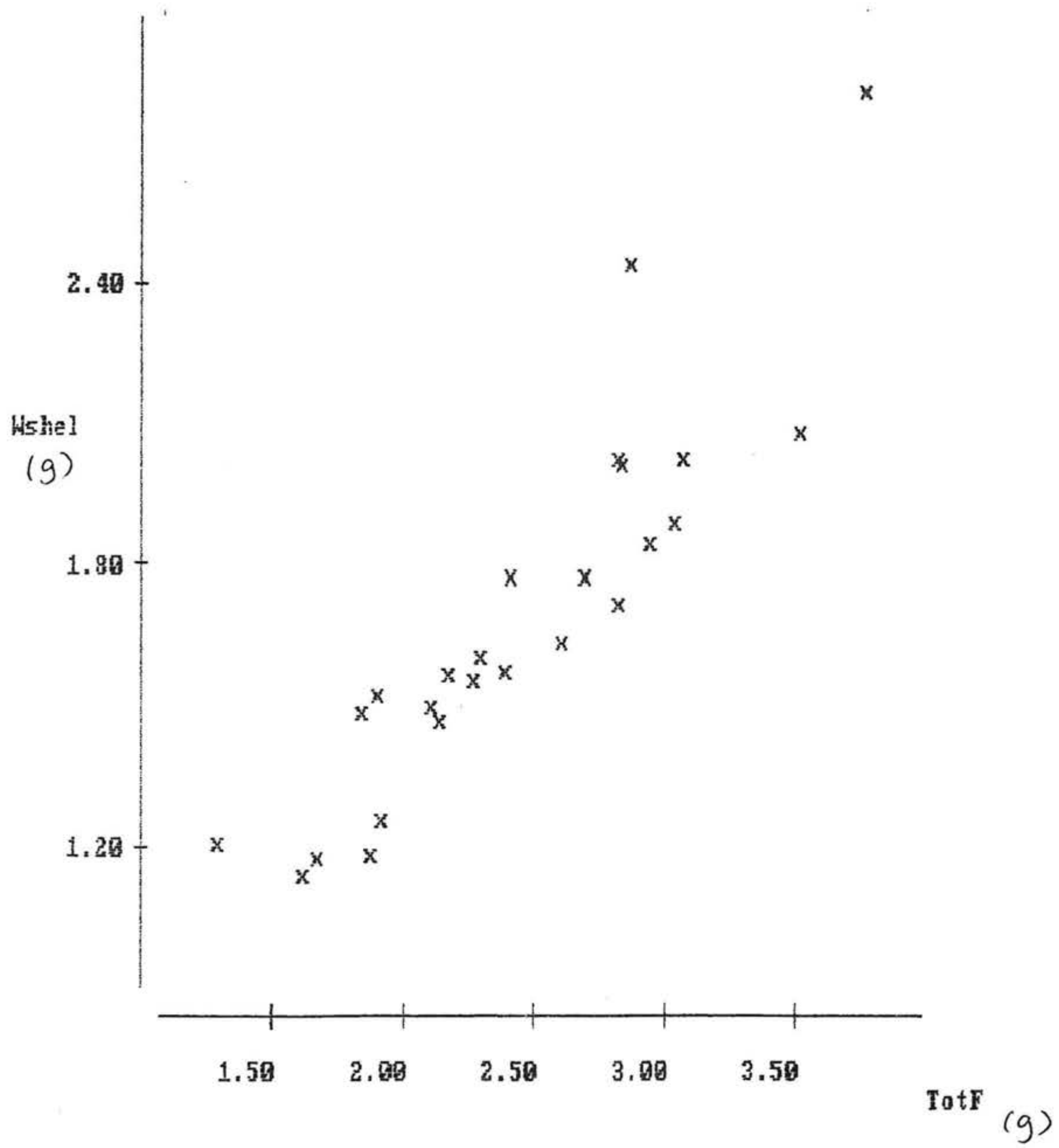

Fig 6 : Graph of Total fruits weight and shell weight (wet)

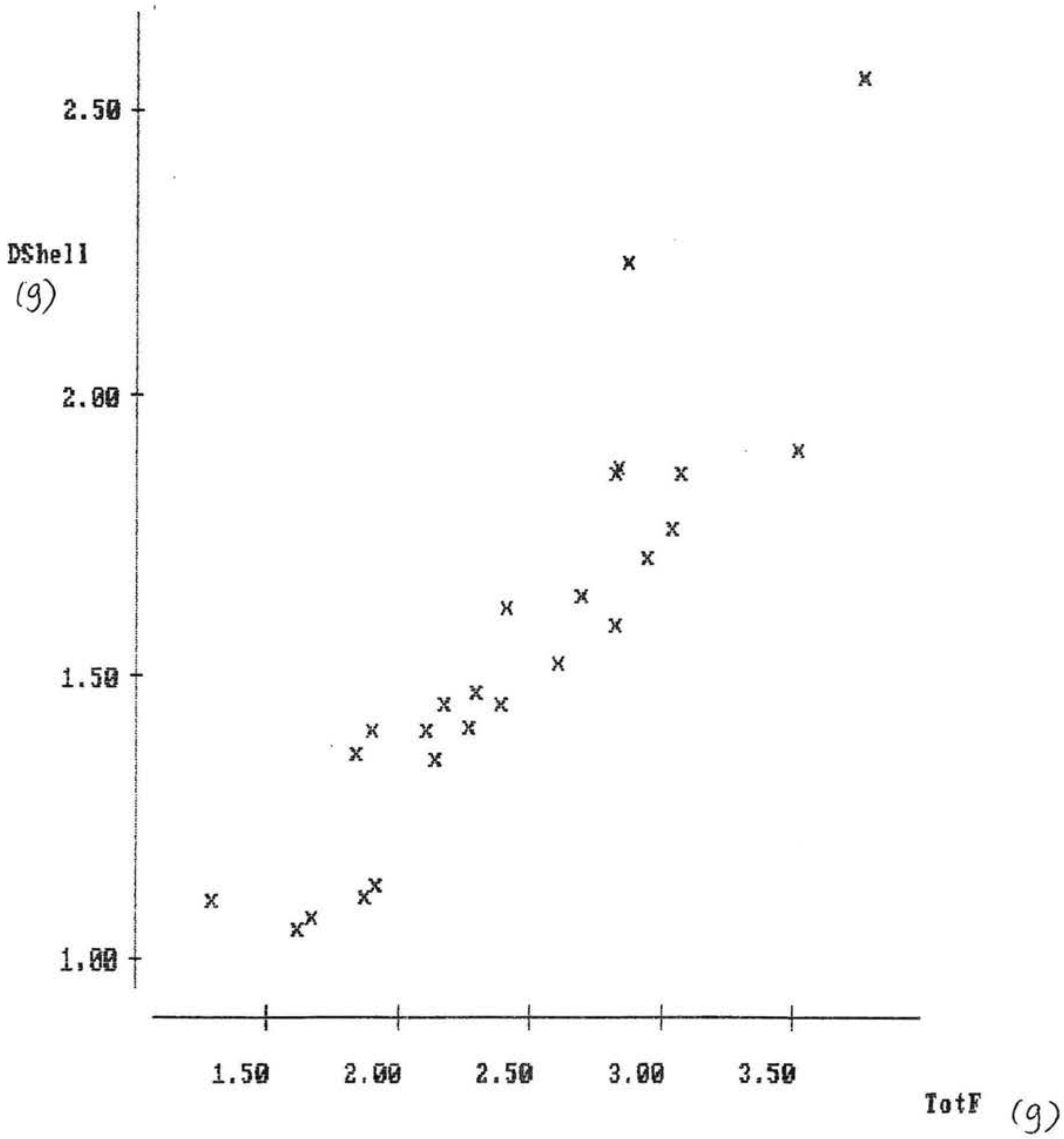

Fig 7: Total fruits weights and shell weight (Dry).

MTB > print c1-c5

ROW	Diameter (mm)	Mass (g)	Germi/Da after Sowing	Growth rate R/Stem (mm/weeks)	R/Leaf (n/weeks)
1	16.01	1.80140	30	5.00	0.00
2	18.83	2.68480	30	2.00	0.00
3	19.77	3.80580	30	1.00	0.00
4	17.65	2.63640	30	10.00	2.00
5	19.33	3.13120	30	6.00	2.00
6	19.28	3.00610	30	16.00	2.00
7	17.19	2.99210	30	14.00	2.00
8	14.90	1.68940	30	3.00	2.00
9	17.32	2.30490	35	8.00	2.00
10	18.75	2.88700	30	11.00	4.00
11	20.62	3.86270	30	18.00	0.00
12	18.78	3.11770	30	0.00	2.00
13	17.65	2.65760	30	5.00	2.00
14	17.05	2.49020	30	2.00	0.00
15	18.47	2.86980	33	11.00	4.00
16	18.79	3.38430	30	19.00	2.00
17	17.18	2.53370	30	4.00	0.00
18	20.16	3.40880	30	13.00	4.00
19	16.29	2.28550	30	5.00	0.00
20	18.26	2.80130	30	5.00	2.00
21	16.94	1.95720	33	2.00	0.00
22	17.72	2.27910	33	9.00	2.00
23	17.75	2.38830	33	0.00	2.00
24	17.03	2.10600	33	3.00	0.00
25	18.04	2.67380	33	2.00	6.00
26	17.71	2.81760	51	3.83	2.67
27	16.95	2.28460	33	7.33	1.33
28	19.15	3.07950	33	10.33	2.33
29	17.52	2.49540	33	0.83	3.00
30	17.72	2.42520	33	0.00	0.33
31	17.13	1.97400	33	1.60	1.67
32	18.29	2.85850	33	5.83	6.00
33	19.60	3.40990	33	3.30	4.70
34	19.97	3.05270	33	6.80	1.67
35	17.59	2.55240	33	11.30	2.33
36	17.23	2.11570	33	0.30	2.83
37	17.26	1.97360	33	12.50	1.00
38	16.59	2.14730	33	1.67	0.67
39	17.70	2.84170	33	2.30	3.33
40	16.10	1.97690	33	0.50	1.33
41	18.34	2.65330	33	12.50	3.00
42	18.15	2.81110	30	14.80	1.67
43	20.42	3.53680	33	3.30	1.33
44	19.47	3.27710	33	7.30	3.00
45	18.47	2.80860	33	3.67	0.30
46	17.47	2.40120	30	8.30	1.33
47	18.43	2.94340	33	3.70	1.00
48	17.14	2.82260	33	7.30	1.33
49	18.16	2.60990	33	0.83	1.33
50	18.16	2.60990	33	0.50	1.67

51	17.96	2.84580	33	1.30	0.67
52	16.75	2.49993	33	0.30	1.33
53	20.58	4.04900	33	0.50	0.02
54	17.84	2.73060	33	9.00	3.00
55	16.35	2.39140	33	11.80	2.00
56	20.00	3.26480	35	1.70	4.33
57	19.28	3.33590	33	0.50	0.02
58	16.46	2.20080	33	1.50	0.80
59	17.51	2.57690	33	0.38	3.00
60	20.60	4.39270	51	5.18	1.64
61	14.49	1.49370	59	1.36	1.30
62	16.26	2.23900	30	0.64	1.80
63	18.20	2.49310	30	1.55	1.30
64	18.05	3.11730	59	0.36	3.20
65	17.84	2.83180	59	5.37	1.30
66	19.03	3.29330	35	3.60	2.90
67	15.81	2.51890	59	3.60	1.10
68	18.61	2.80100	48	7.30	1.90
69	16.15	2.63630	59	0.19	1.80
70	18.50	2.66940	59	2.80	1.80
71	18.46	2.85730	35	1.36	1.80
72	19.36	3.35480	33	0.55	2.90
73	19.58	3.11190	59	4.50	0.50
74	18.56	2.76300	35	6.70	1.20
75	15.39	1.78650	59	0.00	0.00
76	17.55	2.56250	59	0.70	1.33
77	19.47	2.88270	59	4.70	0.50
78	19.10	2.63080	35	1.70	2.70
79	19.56	3.79830	59	1.70	2.90
80	17.76	2.50450	59	1.10	2.20
81	18.30	2.71600	37	3.00	3.50
82	18.99	2.81910	35	0.10	1.33
83	15.56	1.84030	30	2.40	2.36
84	19.11	3.04920	30	8.00	0.72
85	19.93	3.10330	30	1.36	0.20
86	17.18	2.43780	30	5.30	0.72
87	17.43	2.30540	30	4.00	0.36
88	17.80	3.03250	30	2.70	2.64
89	19.64	2.93930	30	1.50	0.00
90	20.12	3.60380	33	5.00	0.90