

BI0138A:: COMPETE\*Apple  
Applesoft 48K, DOS 3.3

Plant  
Competition



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**BIO138A, COMPETE: Plant Competition (Second Edition)**

for the  
Apple II

(Minimum configuration: AppleSoft in ROM, DOS 3.3, 48K)

**Package contents:**

- 1 copy **Teachers' Guide**
- 1 copy **Students' Leaflets**
- Software on one diskette
- Software Purchase Agreement

These notes supplement the **Students' Leaflets** for COMPETE. Refer to these Leaflets for background reading and suggested exercises. The program COMPETE can be used to study the interactions between flowering plants with both real and simulated plants and presents background data in the form of graphs and tables. The **Teachers' Guide** includes a discussion of the program's underlying model and possible extensions to the program.

**TEST THE DISKETTE IMMEDIATELY.** CONDUIT will replace damaged, missing, or unreadable parts of the package within the first 30 days from the date shipped. After 30 days, the customer will be charged \$10 for a replacement copy of the diskette and the actual (list) price for replacement manuals. Complete and return the Software Purchase Agreement to ensure your purchase is covered by our warranty.

**Getting Started**

This diskette can be used without modification on an Apple configured for DOS 3.3.

- 1) If you have an Apple II Plus, Apple IIe, or Apple with Autostart ROM, place the diskette in Drive 1 and turn on your Apple.
- 2) Otherwise, turn on your Apple, place the diskette in Drive 1, and type

PR#n

where "n" is the slot number of the disk controller.  
(Typically, the command will be PR#6. If you have trouble determining "n," see page 3, "Installing the Controller," in The DOS Manual for DOS 3.3 published by Apple Computer, Inc.)

3) Then follow the directions on the screen.

### Notes for the Apple IIe

The program on this diskette was written on an Apple II with an uppercase only keyboard. So that the program functions correctly on your Apple IIe, press the CAPS LOCK key before using the diskette.

### Your First Run

Respond to the program prompts, referring to the Students' Leaflets as needed. Leaflet 2 summarizes the reactions and keywords available in the program. You may also type DEMO in response to the OPTION? prompt to run a demonstration of the program.

Note that if you mistype input, for example, "1,2" instead of "1.2", the program will print the message EXTRA IGNORED and use only the "1" as the input. Once you press RETURN after entering an OPTION, you will be unable to change the input. To correct your mistake, either request the OPTION again and enter the correct input or press RESET (CONTROL-RESET for the IIe) and type RUN to start the program again.

### For the Instructor

Section 9 of the Teachers' Guide, "Extending the Use of the Program," explains how to change the DEMO option to simulate a different experiment, how to use the DEMO option to preset investigations for students, and how to change the keywords to accept abbreviations, for example, EXP for EXPLAIN. All of these modifications require changes to the program and therefore should be made with caution.

Any educational institution purchasing this package may duplicate all or part of the manuals as needed for use within that institution. Thus, you may duplicate the Students' Leaflets in whatever format is convenient and as often as needed.

### Back-up

Since we are providing only one copy of the program, we strongly encourage you to obtain back-up copies of the diskette. You can purchase extra copies directly from CONDUIT for \$10 per diskette.

You can also copy the diskette yourself using the COPY or

COPYA program. For a complete description of these programs, see pages 38-40 in The DOS Manual for DOS 3.3 published by Apple Computer, Inc.

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**For Assistance**

If you have problems loading or using the program, call CONDUIT at (319) 353-5789 and we will help you solve the problem.

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# Chelsea Science Simulations

## Plant Competition CMPETE

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 **Edward Arnold**

# Chelsea Science Simulations

Plant  
Competition  
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#### NOTES ON THE PROGRAM

All of the Chelsea Science Simulation programs can be controlled by the use of keywords, with the exception of the programs SCATT1, 2 and 3 which are of a dialogue style. Some of the keywords are common to most of the programs; START, GO, EXPLAIN, HELP, DEMO and FINISH. In particular DEMO provides a demonstration of the program for the teacher. The keywords needed and their functions are described in the Teachers' Guide and are listed on Students' Leaflet Z.

Some structured paths through the programs have been included and can be called by the use of certain keywords. These lead the user through a series of operations to set values and display results. However the style of program allows teachers to construct any sensible pathway they may want to meet the needs of different teaching methods, student abilities and class groupings. Instructions on how to do this are provided in the Teachers' Guide.

## ACKNOWLEDGEMENTS

The new edition of the Chelsea Science Simulations, has been developed at the Educational Computing Section of Chelsea College supported by funds from the Educational Computing Section, Chelsea College and the Microelectronics Education Programme. The work has been carried out under the direction of R. Lewis (formerly Project Director now at S. Martin's College, Lancaster) and Dr. Margaret Cox (Project Director) also D. L. Want (formerly Assistant Director, Science now Director of Eastern Region MEP Centre), Mrs Sophie McCormick (Assistant Director, Science) and P. W. Smith (Assistant Director, Software). Valuable advice has been provided by Professor D. C. Johnson (Project Consultant), Mrs Deryn Watson (Assistant Director, Humanities) and M. E. Leveridge (Luton Sixth Form College).

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The publishers would like to thank the following for permission to use illustrations

Figure C1 & C2 } based on figures from Netherlands J. Agric. Sci  
Figure D1        } 16, 110-112  
Figure E1

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### Students' Leaflets

- A Plant growth
- B Simulated growth in monoculture
- C Plant growth in mixtures
- D Simulated growth in mixtures
- E Interaction below the ground
- Z List of keywords

## 1 INTRODUCTION

The study of interactions between flowering plants is an important part of ecology and a considerable amount of experimental work has been carried out in recent years to investigate the factors which are involved. Some of these studies are presented here. Since experimental work with real plants often takes a long time, it is not very suitable for students, but the computer simulation of plant growth enables students to plan an investigation and to carry it out without the long delay usually associated with growth experiments. This unit thus describes investigations with both real and simulated plants, and presents background data in the form of graphs and tables.

The computer program CMPETE is based on a mathematical model of plant growth devised by Baeumer & De Wit (1968) and described in section 8. Their experiments are briefly described in Students' Leaflet B. They grew barley, oats and tall and dwarf peas in rows on their own and in mixtures of two kinds in alternate rows. The dwarf peas were var. Pauli and the tall peas var. Mechelse Krombek.

Figure 1 shows the type of graphical output that is obtained with CMPETE. The growth of the plants is shown as the dry mass per square metre on each day from day 36 to day 78 after planting.

TALL peas grown on their own in  
ROWS 20 cm apart  
Final TALL peas dry mass = 648 g/sq m

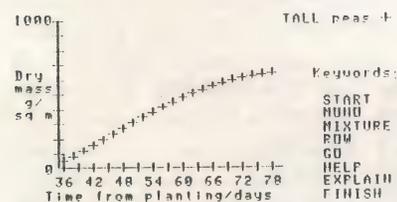


Figure 1 Screen printout from CMPETE showing the growth of tall peas in rows 20 cm apart.

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The program is controlled by a series of keywords which specify how the computer plants are to be grown. The keywords are used when Option ? appears on the screen. They are listed in Table 1 and with the exception of DEMO, in Students' Leaflet Z.

Keyword	See Students' Leaflet
START	B
GO	B
HELP	-
FINISH	-
MONO	D
MIXTURE	D
ROW	B
EXPLAIN	-
DEMO	-

Table 1 List of keywords with references to the Leaflets describing them.

The keyword HELP enables the user to obtain a list of keywords and their meanings on the screen. It needs to be used with care as it destroys the current screen display. The keyword EXPLAIN returns the user to the explanation at the beginning of the program. The keyword DEMO provides a demonstration without the user entering any values.

When first using the simulation it is best to begin with the keyword START. This provides a guide to the values which the user needs to set. The current values which have been set by the user, or are assumed in default of set values, are shown on the screen. GO is used to obtain a set of results. FINISH ends the use of the program.

## 2 EFFECTS OF CROWDING ON PLANT GROWTH

Before using the computer simulation it is useful to show that plants do affect one another's growth. It also provides an opportunity to see the pattern of growth of the plants referred to in the simulation.

Different numbers of seeds of a particular species can be planted in soil, sawdust or vermiculite in seed trays. Alternatively a single large tray can be subdivided and different numbers of seeds planted in each section. The trays need to be watered to keep the soil damp. A sheet of glass or perspex on top of the tray prevents the seedlings from drying out over a weekend. If the tray is kept in a place where the light intensity is greater on one side than another, turn the tray round periodically so that the seedlings are evenly illuminated. The growth of the seedlings can be compared after about two weeks. Table 2 shows data obtained with barley grains sown at four different planting densities in a circular washing-up bowl divided into four. The percentage germination of the grains was lowest in the most crowded quarter and the heights of the seedlings growing there were significantly shorter than elsewhere.

Quarter	No. of grains	% germination	Heights of seedlings/mm (mean and s.d.)
A	25	100	153.8 ± 32.0
B	50	100	160.5 ± 36.9
C	100	100	152.5 ± 38.3
D	500	82	139.7 ± 43.0

Table 2 Percentage germination and heights of barley seedlings 15 days after planting in four different degrees of crowding.

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### 3 MEASUREMENT OF GROWTH

Seedling height was used to measure the growth of the barley seedlings recorded in Table 2. Students' Leaflet A introduces students to this and other ways of measuring growth and asks them to consider the advantages and disadvantages of each method. The data on the growth of oat seedlings in Table A1 is taken from Ashby (1938). He does not give any units for his height measurements and those in the table have been inferred from other work.

The measurements show that the pattern of growth which is obtained depends upon how growth is measured. The linear increase in the height of the oat plants contrasts strongly with the exponential increase in the number of leaves and the wet and dry masses. Both height and number of leaves are continuous measurements which leave the plants undisturbed, but they do not allow for root growth nor for any increase in size, apart from total height. The mass measurements disturb the plants and in the case of dry mass destroy them, but they measure the complete growth. The dry mass measurement overcomes the distorting effect that fluctuations in water content can produce in the wet mass. Question D5 is a reminder that these measurements may not be appropriate for a farmer who is growing a crop for its seeds or fruits.

### 4 SIMULATED GROWTH IN MONOCULTURE

The monoculture experiments are introductory ones which familiarise a student with the use of a computer to simulate plant growth. At the same time they provide control data for comparison with the simulated growth of mixtures of different kinds of plants in a later investigation.

The growth of the different kinds of plants can be simulated by different students. Figure 2 shows the graphs obtained using oats. The other kinds of plants show similar results. In each case the more closely spaced plants show a poorer yield per row since there is a shortage of resources, but an increased yield per area since there are more plants present.

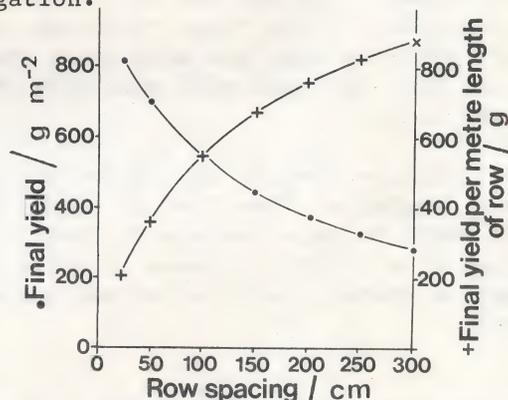


Figure 2 Final dry mass per area and per row. Results from computer simulation of oat growth.

### 5 SIMULATED GROWTH IN MIXTURES

Students' Leaflet C shows students the appearance of the plants when grown in mixtures and the relative light intensities reaching each kind. Baeumer & De Wit (1968) found that there was little or no interaction between the plants below the surface of the soil. Some of their evidence is presented in Leaflet E. They concluded that light intensity was the main factor affecting the competition and that the amount of light a plant received was largely determined by its height. Leaflet D shows how the heights of the real plants changed with time (Figure D1) and asks students to predict the relative success of the plants when grown in mixtures.

The rest of Leaflet D gives students the opportunity to plan an investigation in order to answer questions D2 to D4. Different individuals or groups of students

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can investigate different mixtures, but some mixtures show more interesting results than others. The interactions between barley and oats are particularly worth studying.

When any two kinds of plants are grown together the final yield per square metre of the plant to the right in the following sequence is always greater, with one exception.

dwarf peas - tall peas - oats - barley

When barley and oats are grown together, barley gives the greater final yield at row distances below about 180 cm and oats give the greater final yield at row distances above this value. With close spacing of the rows the taller initial growth of the barley hinders the growth of the oats, but at wide spacings the barley no longer has much effect on the oats, whose greater final height reflects its greater final yield.

When comparing the growth of plants in mixtures with their growth in monoculture it is important to double the mixture figures to allow for only half the number of plants of each kind being grown. Barley always shows greater final yields in mixtures than in monoculture. Oats show greater final yields in mixtures with dwarf peas at all row distances, with tall peas at row distances greater than 45 cm and with barley at row distances greater than 490 cm. Tall peas show greater final yields in mixtures with dwarf peas at all row distances and with oats at row distances less than 58 cm. In all other cases the yields in mixtures are less than in monoculture. Barley always shows a greater yield in a mixture than in a monoculture, since other kinds of plants inhibit its growth less than it inhibits itself. Height during the earlier part of the growth period is seen to be a good guide to the final yield and more important than the final height. However, when the rows are wide apart the plants do not restrict one another's light and then oats and tall peas show increased yields compared to their growth in monoculture.

At row distances from 34 to 115 cm the total final yield of a mixture of barley and oats is greater than that of either kind grown on its own. This suggests that it would be an advantage to grow a mixture rather than a pure crop, but the advantage of a slight increase in yield needs to be considered against increased problems of sowing, cultivating and harvesting different kinds of plants together.

## 6 INTERACTION BELOW THE GROUND

The possibility that light intensity is not the only factor affecting competition between plants is considered in Leaflet E. No subterranean competition was found in Baeumer & De Wit's experiments, but some secondhand data is introduced so that students do not assume that this is always true.

The work of Stern & Donald (1962) on the interaction of subterranean clover and rye-grass shows how conditions in the soil can affect the balance between two species. At low nitrogen levels the clover is more successful than the grass, since the nitrogen-fixing bacteria in its roots can make use of gaseous nitrogen. Where there is sufficient nitrogen for the grass its growth above ground reduces the light supply to the clover.

## 7 FURTHER WORK

Additional practical work on plant competition can be carried out, such as the investigation of the interaction between two varieties of white clover,

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*Trifolium repens*, described by the Nuffield Advanced Biological Science Project (1970b). The investigations with the simulated crop plants described above can be related to observations of actual crops in the field. The identity of the crops, and their heights and row spacing can easily be observed together with the presence of any weeds. Many aspects of weeds are described by Salisbury (1964) and the methods used to control them provide a useful study.

Competition and chemical interactions have important consequences in subsequent generations because of the effects of natural selection. The form of the selection will depend upon whether the competing plants are varieties of the same species and thus able to interbreed, or whether the plants belong to separate species, which are reproductively isolated. Jones & Wilkins (1971) give many examples and a general discussion of the subject. A particularly useful study, which links with plants described in this unit, is selection for and against cyanogenesis in white clover. Darlington & Bradshaw (1963) describe experimental work which can be undertaken.

## 8 COMPUTER MODEL

When using a computer simulation it is important for students to remember that they are using a mathematical model of plant growth and not growing real plants. The results depend upon the accuracy of the model and the limits within which it is used. The model is not valid with very close spacing of the rows and the program prevents the use of such values. Some of the results from the real experiments used by Baeumer & De Wit to develop their mathematical model are given in Table 3. They can be compared with results from the simulated growth to see how close the simulated results are to the real results.

Time from planting / d	Monoculture - dry mass / g m <sup>-2</sup>			
	Barley	Oats	Dwarf peas	Tall peas
36	117	81	52	60
50	426	319	240	262
64	588	503	445	485
78	858	789	647	605

Time from planting / d	Mixtures - dry mass / g m <sup>-2</sup>					
	Barley - Oats		Oats - Dwarf peas		Dwarf peas - Tall peas	
36	62	30	41	23	16	29
50	235	142	187	90	68	147
64	375	165	401	126	76	347
78	512	308	687	185	100	500

Table 3 Dry mass of barley, oats, dwarf and tall peas grown in monoculture and in mixtures at a row spacing of 25 cm.

In the mathematical model devised by Baeumer & De Wit (1968) the yield on any particular day is calculated from that on the previous day by using the heights of the plants and several other values derived from their field experiments. The heights are ignored until the combined dry masses of the two kinds of plants exceeds 200 g m<sup>-2</sup>. The yield of one kind of plant on day T+1 is given by the equation:

$$G_1 = M_1 \times R_1 \quad \dots\dots\dots(1)$$

where  $G_1$  is the dry mass on day T + 1  
 $M_1$  is the maximum dry mass at high densities  
 $R_1$  is the relative space occupied by the plants on day T + 1

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The relative spaces occupied on day T + 1 by two kinds of plants 1 and 2 is calculated from these equations:

For plant 1

$$R1_1 = \frac{U1_1 \times R1}{\frac{(H1 \times R1 + H2 \times R2) \times (U1_1 - U1)}{H1} + U1} \dots\dots\dots(2)$$

For plant 2

$$R2_1 = \frac{U2_1 \times R2}{\frac{(H2 \times R2 + H1 \times R1) \times (U2_1 - U2)}{H2} + U2} \dots\dots\dots(3)$$

where R1 and R2 are the relative spaces occupied by plants 1 and 2 on day T  
R1<sub>1</sub> and R2<sub>2</sub> are the relative spaces on day T + 1  
U1 and U2 are the saturation factors of plants 1 and 2 on day T  
U1<sub>1</sub> and U2<sub>1</sub> are the saturation factors on day T + 1  
H1 and H2 are the heights of plants 1 and 2 on day T

When plants are grown in monoculture, equations (2) and (3) simplify to:

$$R1_1 = \frac{U1_1 \times R1}{R1 (U1_1 - U1) + U1}$$

$$R2_1 = \frac{U2_1 \times R2}{R2 (U2_1 - U2) + U2}$$

In the simulation the maximum yields and saturation factors are calculated from a series of polynomial equations of time T based on the graphs given by Baeumer & De Wit (1968).

## 9 EXTENDING THE USE OF THE PROGRAM

This program contains 9 options. A particular option or sequence of options is called by typing the appropriate keyword. These keywords with their option numbers are listed in Table 4. The input necessary for each option, the limits of the range of acceptable values and the data structure used within the program for each option are also listed. An \* is used to show that the user must input that value. An / indicates that a variable number of inputs can be accepted.

The keyword data lines are 5800-5890. Abbreviated and alternative forms of some keywords have been included. To add any other alternative keywords, two data lines must be added to the program in the data block. The lines reserved for extra keywords are 5830-5890. For example to allow the keyword MONOCULTURE to call option 2, add the following two lines:

```
5830 DATA "MONOCULTURE"  
5831 DATA "2,*"
```

The keyword will not appear in the HELP list unless a message is added.

```
5830 DATA "MONOCULTURE, select only one kind of plant"
```

## Plant Competition

Option number	Keyword	Input and limits	Data structure
2	MONO	select one kind of plant (oats, barley, dwarf, tall)	"2,*"
3	MIXTURE and MIX	select two kinds of plant (oats, barley, dwarf, tall)	"3,*,*"
4	ROW and ROWS	row spacing (20-500)	"4,*"
5	GO	none	"5"
6	HELP	none	"6"
7	EXPLAIN	none	"7"
8	PAUSE	none	"8"
0	FINISH	none	"0"
1	START	choose mono or mix, select plants, set row spacing	"1,/"

Table 4 List of options and keywords.

In addition to the keywords listed in Table 4 the keyword DEMO can be used. This is not associated with any one option but calls a sequence of options as shown below:

```
5820 DATA "DEMO"
5821 DATA "3,BARLEY,OATS,4,50,5"
```

Therefore the following sequence occurs

3	MIXTURE	the model uses barley and oats
4	ROW	the supplied value of 50 cms is used
5	GO	the calculations begin and the results are displayed

The teacher may wish to introduce a new sequence appropriate to a particular teaching scheme. This can be done in the same way as shown above with DEMO using any two spare lines in the keyword block. Supplied values can be provided as with DEMO or the user can be asked to enter the values in the example shown below:

```
5834 DATA "DEMO2"
5835 DATA "3,**,4*,5"
```

When continuing these sequences it is important to consider the order carefully and to test the effect. For permanent alterations the program must be resaved.

# Plant Competition

## 10 REFERENCES AND FURTHER READING

### 10.1 References

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### 10.2 Further reading

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STUDENTS' LEAFLET A - PLANT GROWTH

*Some seed fell among thistles; and the thistles shot up and choked the corn, and it yielded no crop. Mark 4:7.*

For many centuries man has recognised that plants interact with one another. The commonest form of interaction arises when plants compete for some resource whose supply is insufficient for their needs. Competition can occur within a single plant, or between plants of the same or different species, and gardeners and farmers often take steps to reduce it. A plant is pruned to reduce competition within itself. A crop is thinned to reduce competition between the crop plants and weeded to reduce competition with other species.

Most plants grow in soil. They must obtain all their requirements for growth from this soil and from the air above it. Their main needs are sufficient light and carbon dioxide for photosynthesis, oxygen for respiration, mineral salts for nutrition, and water for transport, support and many metabolic processes. The availability of each of these resources depends not only on how much is present in the plant's surroundings, but also on how many other plants are growing there. The more plants there are, the less there is for each plant.

A quantitative study of plant growth depends upon some way of measuring it. There are several methods that can be used, each with advantages and disadvantages. Ashby (1938) used four of them to study the growth of oats. He soaked 100 oat grains for one day then planted them. Groups of 10 plants were harvested and measured at weekly intervals after planting. His results are given in Table A1.

Time from planting/d	Height /mm	Number of leaves	Wet mass /g	Dry mass /g	
0	-	-	0.07	0.041	Table A1 Growth of Oat Plants. Data from Ashby (1938).
7	-	-	0.11	0.029	
14	95	1	0.21	0.033	
21	170	2	0.36	0.044	
28	253	3	0.87	0.095	
35	380	4	1.94	0.177	
42	485	8	4.05	0.380	
49	550	10	8.35	0.760	
56	657	13	17.00	1.500	
63	758	26	30.30	2.430	
70	850	48	60.80	5.100	

Plot a graph of each of these measurements of growth against time since they were planted. The graphs can be compared most easily if they are drawn together on the same side of the graph paper, but you will need to use four different vertical axes.

- A1 *To what extent do these measurements show similar patterns of growth?*
- A2 *What are the advantages and disadvantages of each of these as measurements of growth?*
- A3 *The dry mass of the plants is the most commonly used measurement of growth. Is it likely to be a good method for the farmer to judge the degree of success of his crops? Give reasons for your answer.*

Ashby, E. (1938) *School Science Review*, 19, 409-418

EMANE

### Plant Competition

#### STUDENTS' LEAFLET B - SIMULATED GROWTH IN MONOCULTURE

In recent years many experimental investigations have analysed the ways in which plants interact. Cultivated plants have often been used, since a full understanding of the factors affecting their growth is of considerable economic importance. Investigations of this type are not difficult to carry out, but they often require more time and space than are available in schools and colleges. The computer program CMPETE simulates plant growth to enable you to investigate some of the factors affecting plant competition in a much shorter time.

The simulation is based on outdoor experiments in the Netherlands with real plants of four kinds - barley, *Hordeum* sp. oats, *Avena sativa*, and dwarf and tall varieties of field pea, *Pisum sativum*. Baeumer & De Wit (1968) grew the plants in rows in a heavy, but well structured clay soil. The tall peas were supported by wire gauze 120 cm high. There was sufficient rainfall during the experiments to ensure that the plants were not short of water. The plants were kept from weeds by herbicides and weeding.

In CMPETE you can choose the kind of plant you wish to grow and the density of planting. The distance between the rows is used to measure this density. The growth is measured as the dry mass of the aerial parts of the plants per m<sup>2</sup> at intervals from day 36 to day 78 after planting. In the questions which follow the dry mass on day 78 is called the final dry mass, although growth continues after this time.

When first using CMPETE it is best to type START when Option ? appears on the screen. You will then be guided through the program. Grow one of the kinds of plants on its own, i.e. in monoculture. To obtain the kind of plant type BARLEY, OATS, DWARF or TALL. Use a row spacing of about 100 cm. Figure B1 shows an example using oats. The results are shown in Figure B2.

The plants you can use are:

- BARLEY
- OATS
- TALL peas
- DWARF peas

You have to decide the kind of plant and the distance between the rows. You are then given a graph of the increase in dry mass of each kind of plant from 36 to 78 days after planting.

Type START to be guided through the program, or one of the other keywords from student leaflet Z.

Which option: ? START

Do you want to grow plants

- 1 On their own
- 2 In mixtures ? 1

What kind of plant? OATS

How far apart are the rows (20-500 cm): ? 100

OATS plants grown on their own in  
ROWS 100 cm apart  
Final OATS dry mass = 539 g/sq m

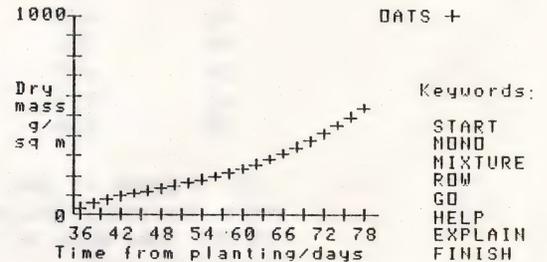


Figure B1 Screen printout from CMPETE showing the use of the keyword START to obtain the results shown in figure B2.

Figure B2 Screen printout from CMPETE showing the growth of oat plants in rows 100 cm apart.

When Option ? appears again on the screen you can alter the values you chose by using a series of keywords, which are listed in Leaflet Z. Typing ROW allows you to change the distance apart of the rows. Typing PLANT allows you to change the kind of plant you are working with. The keywords MIXTURE and MONO are described in Leaflet D. After making any changes you wish, you need to type GO to obtain the results.

## Plant Competition

Students' Leaflet B continued

Select one kind of plant and use the computer to simulate its growth at several different planting densities. Suitable values are row spacings of 25, 50, 100, 175 and 250 cm. The minimum row spacing is 20 cm and the maximum is 500 cm.

B1 Compare the growth from day 36 to day 78 with that which must have taken place in the first 35 days. Was this early growth at a faster or a slower rate?

Make two graphs from the results of your investigations. In the first, plot the final dry mass per  $m^2$  against the row spacing. In the second, plot the final dry mass per metre length of row against the row spacing.

B2 What effects does the closer spacing have on the final dry mass per  $m^2$  and the final dry mass per metre length of row? Explain these effects.

If time permits repeat the work with a different kind of plant and summarise the similarities and differences between the growth of the plants.

Baeumer, K. & De Wit, C.T. (1968) *Netherlands Journal of Agricultural Science*.  
16, 103-122.

Chelsea Science Simulation Project

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Plant Competition

STUDENTS' LEAFLET C - PLANT GROWTH IN MIXTURES

The more densely that plants grow, the greater is their interference with each other's growth. One of the main factors which is likely to be in short supply is light. A plant's ability to obtain light will partly depend upon its height compared to that of its neighbours. Baeumer & De Wit grew mixtures of two kinds of plants at a time in alternate rows. The light reaching two such mixtures is shown in Figures C1 and C2. The values given for the light intensity are percentages of the values above the plants.

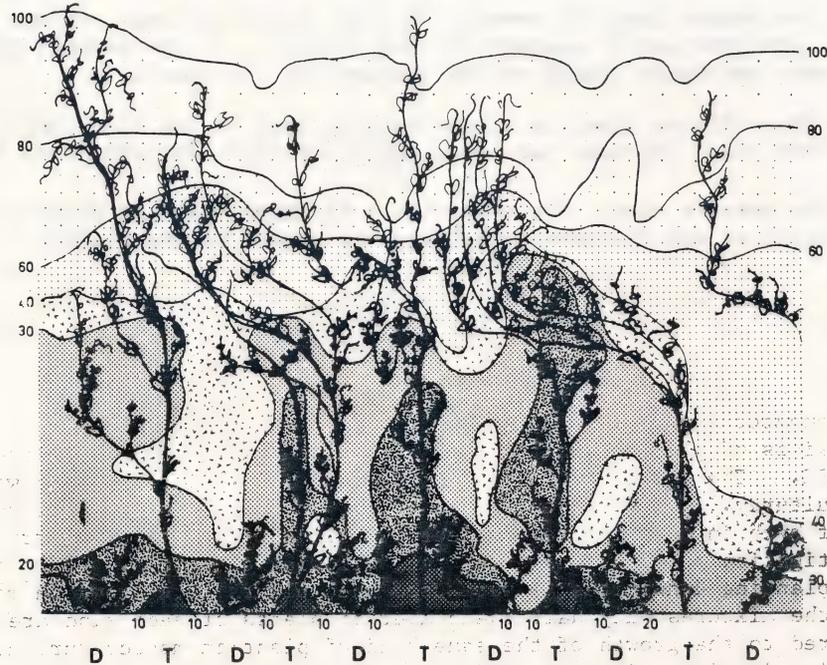


Figure C1

Light reaching a mixture of dwarf peas (D) and tall peas (T) grown in alternate rows. From Baeumer & De Wit (1968).

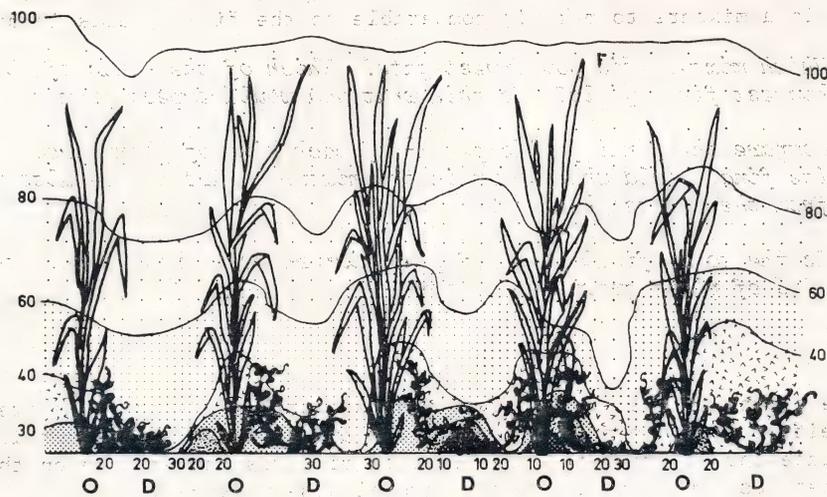


Figure C2

Light reaching a mixture of oats (O) and dwarf peas (D) grown in alternate rows. From Baeumer & De Wit (1968).

C1 Which of these plants shown receive high and which receive low light intensities? Explain the reason for this.

Baeumer, K. & De Wit, C.T. (1968) *Netherlands Journal of Agricultural Science*. 16, 103-122

## Plant Competition

### STUDENTS' LEAFLET D - SIMULATED GROWTH IN MIXTURES

Figure D1 shows the increase in height of Baeumer & De Wit's plants when grown in monoculture in rows 25 cm apart.

D1 *If a height of a plant is the main factor affecting the amount of light reaching it, which kind of plant will receive the greatest amount of light and which the least? Which mixtures are likely to result in one kind of plant being much more successful than the others?*

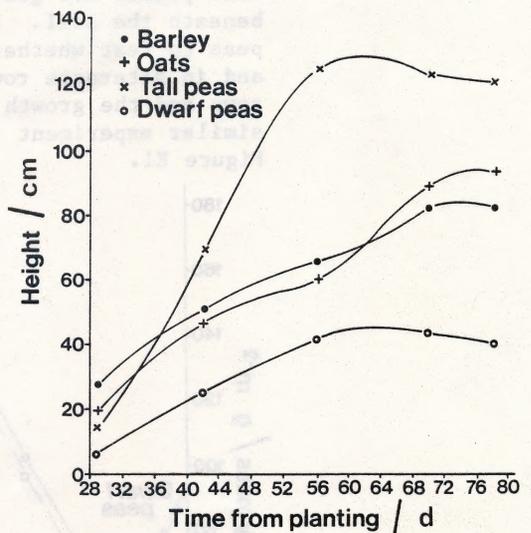


Figure D1 Growth in height of barley, oats, and dwarf and tall peas in monoculture. After Baeumer & De Wit (1968).

The computer simulation can be used to study the interaction of any two of the four kinds of plants at different planting densities by typing the keyword MIXTURE. (The keyword MONO is used if you wish to return to growing plants in monoculture). The different kinds are grown in alternate rows, so that there is 50% of each in the mixture. Select two kinds of plants and carry out an investigation aimed at answering the following questions. It is best to use the same planting densities as were used when plants were grown in monoculture. With the mixtures only half the number of plants of each kind are being grown compared to the growth of the same kind of plant in monoculture at the same planting density. It is therefore necessary to double the final yields of each plant in a mixture to make it comparable to the final yields in monoculture.

- D2 *Which mixture did you investigate? Which of the kinds of plants gave the highest final yield? Is this what you would expect from the plants' heights?*
- D3 *Compare the final yields per m<sup>2</sup> of each kind of plant grown on its own with its final yield when grown in the mixture. Are the results what you expect from the plants' heights?*
- D4 *Is the total final yield of your mixture ever greater than that of either kind of plant grown on its own?*

If the growth of the two kinds of plants together results in a greater yield than either kind grown on its own, it seems at first sight that it would be an advantage for a farmer to grow crops in mixtures rather than on their own. This is sometimes done, but there are several disadvantages.

- D5 *What disadvantages to a farmer do you think there are in growing mixtures of two kinds of plants together in the same field, even if it gives greater yield?*

Baeumer, K. & De Wit, C.T. (1968) *Netherlands Journal of Agricultural Science*, 16, 103-122.

Plant Competition

STUDENTS' LEAFLET E - INTERACTION BELOW THE GROUND

When plants are grown close together they may interfere with each other's growth beneath the soil. Baeumer & De Wit carried out some greenhouse experiments with peas to test whether this occurred. Dwarf and tall peas were grown on their own and in alternate rows. Vertical partitions were placed in the soil between the rows and the growth of these plants was compared with the growth of plants in a similar experiment in which partitions were not used. The results are shown in Figure E1.

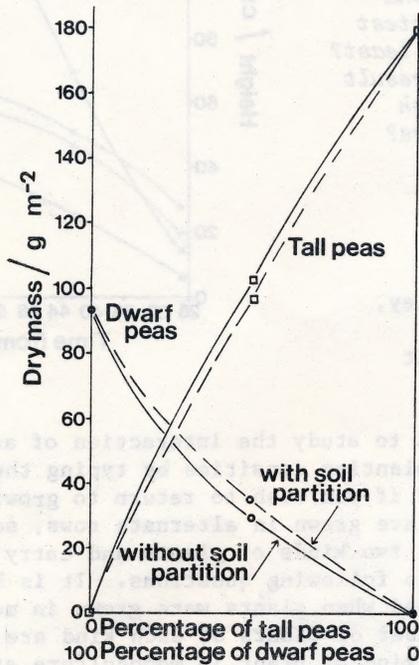


Figure E1 Growth of dwarf and tall peas in monoculture and in mixtures in alternate rows either with or without vertical partitions. After Baeumer & De Wit (1968).

E1 Is there an interference between the dwarf and tall peas below the surface of the soil? Give reasons for your answer.

E2 Will a similar result apply with oats and barley?

In a completely different set of experiments carried out in Australia, Stern & Donald (1962) compared the growth of a mixture of clover and grass when different amounts of a nitrogen-containing fertilizer were added. The plants used were subterranean clover *Trifolium subterraneum* and *Lolium rigidum*, a species of rye-grass not usually found in the British Isles. The results they obtained are shown in Table E1.

Mass of nitrogen added/g	0	2.5	7.5	22.5
Density of clover after 67 days/plants dm <sup>-2</sup>	28.1	27.7	25.7	25.4
Density of clover after 133 days/plants dm <sup>-2</sup>	26.9	27.2	22.9	5.9
Dry mass of grass after 133 days/g dm <sup>-2</sup>	1.18	2.84	5.32	12.86

Table E1 Growth of a mixture of subterranean clover and rye-grass with different amounts of a nitrogen-containing fertilizer.

## Plant Competition

### Students' Leaflet - E continued

E3 Which is the most successful species at low, and which at high nitrogen levels? Suggest a reason for the results obtained.

In order to eliminate root competition, Stern & Donald constructed an apparatus in which mixtures of clover and grass could be grown in alternate sections separated by wooden partitions. An additional supply of nitrogen was added to the grass at the rate of  $32 \text{ g m}^{-2}$ . Results from an experiment in which the growth of the clover in monoculture was compared with its growth mixed with grass are shown in Table E2.

Time from sowing/d	54	72	93	107	114	134
Density of clover in monoculture /plants $\text{dm}^{-2}$	27.8	28.3	28.8	25.5	25.0	18.3
Density of clover when mixed with grass plants $\text{dm}^{-2}$	28.8	28.3	26.5	1.7	0.0	-

Table E2 Growth of subterranean clover in monoculture and mixed with rye-grass.

E4 What is the effect of the grass on the clover in the absence of root competition. What might be the cause of this effect?

E5 What treatment do these experiments suggest would be suitable for removing clover from the lawn?

Baumer, K. & De Wit, C.T. (1968) *Netherlands Journal of Agricultural Science*.  
16, 103-122

Stern, W.R. & Donald, C.M. (1962) *Netherlands Journal of Agricultural Science*.  
13, 615-623.

Plant Competition

STUDENTS' LEAFLET Z - LIST OF KEYWORDS

Keyword	Function
START	Provides guidance through the program.
HELP	Provides an explanation of the keywords.
GO	Operates the model.
MONO	To select only one kind of plant.
MIXTURE	To select two kinds of plants.
ROW	To select row spacing.
EXPLAIN	Provides an explanation of the program.
FINISH	Ends the program.

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