King's College London (KQC) University of London

SCIENCE SIMULATIONS LABORATORY

PLANT COMPETITION

STUDENTS' MANUALS (Version 1.02.2003)

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King's College London May 10th 1988

STUDENTS' MANUAL 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
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

Table A1 Growth of Oat Plants. Data from Ashby (1938).

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

STUDENTS' MANUAL 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 ***Plant Competition*** simulates plant growth to enable you to investigate some of the factors affecting plant competition in a much shorter time.

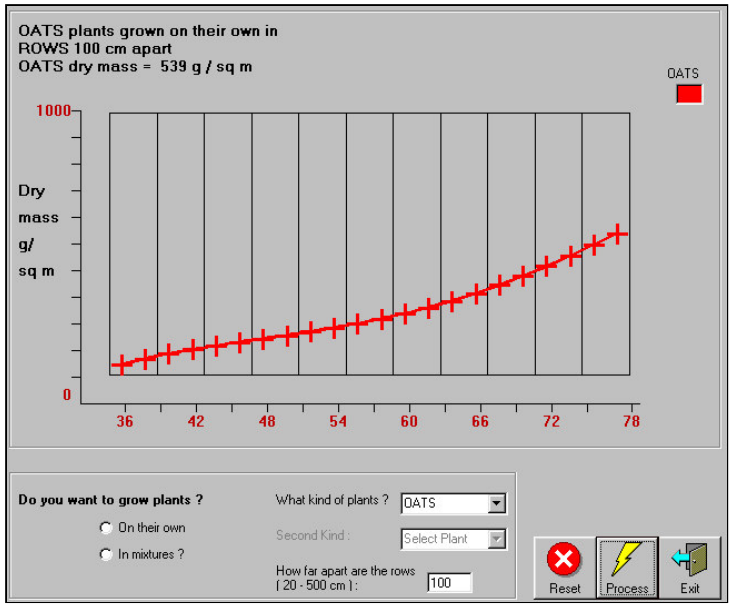
The simulation is based on outdoor experiments in the Netherlands with real plants of four kinds – barley, *Hordeum* sp. oats, *Avena sativa,* and dwarf and tall varieties of field pea, *Pisum sativum.* Baeumer & De Wit (1968) grew the plants in rows in a heavy, but well structured clay soil. The tall 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 ***Plant Competition*** 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 m² 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.

In ***Plant Competition***, at first, decide if you want to grow plants *on their own* or in *mixtures*. If you choose the first option select a kind of plant in the *What kind of plants?* drop down list. If you choose the second option you will also have to select a kind of plant in the *Second Kind* drop down list. Finally type the row spacing in centimetres, valid values are between 20 and 500 cm. Figure B1 shows an example using only oats and a row spacing of 100 cm

Figure B1

Output example showing the growth of oats plants in rows 100 cm. apart.



The plants you can use are:

BARLEY, OATS, TALL peas, and DWARF peas

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 m2* 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.

STUDENTS' MANUAL 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.

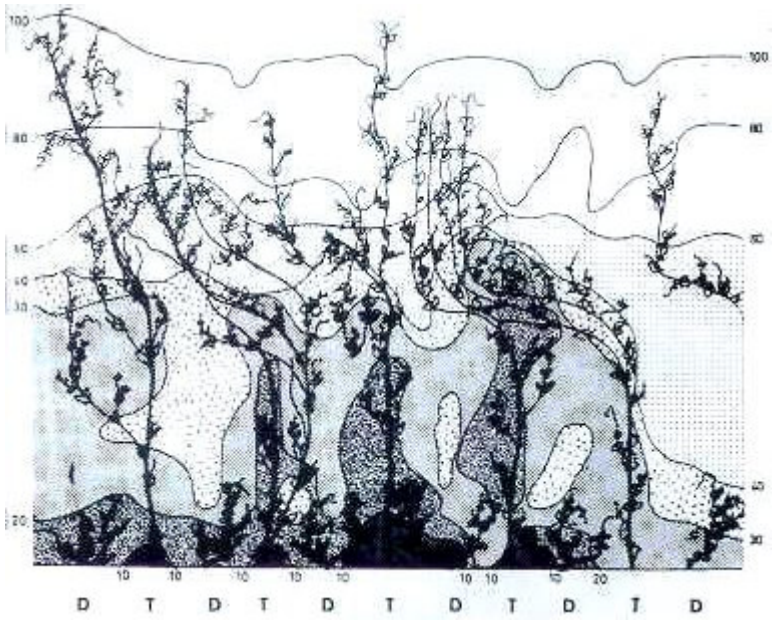


Figure C1

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

D dwarf peas

T tall peas

O oats

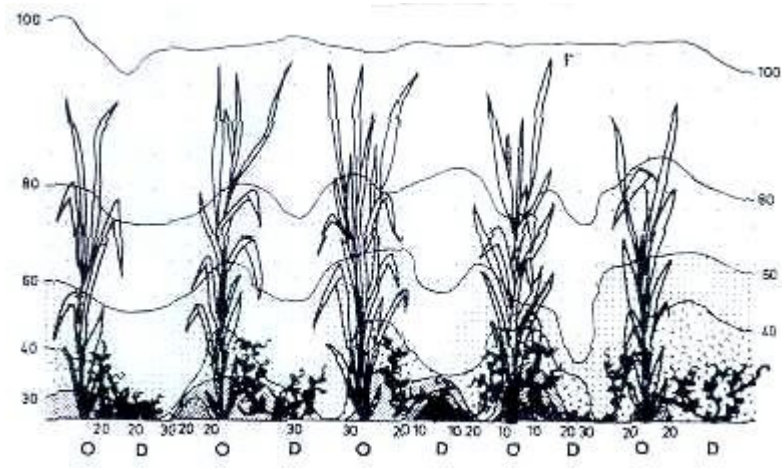


Figure C2

Light reaching a mixture of oats (0) 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.

STUDENTS' MANUAL 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?*

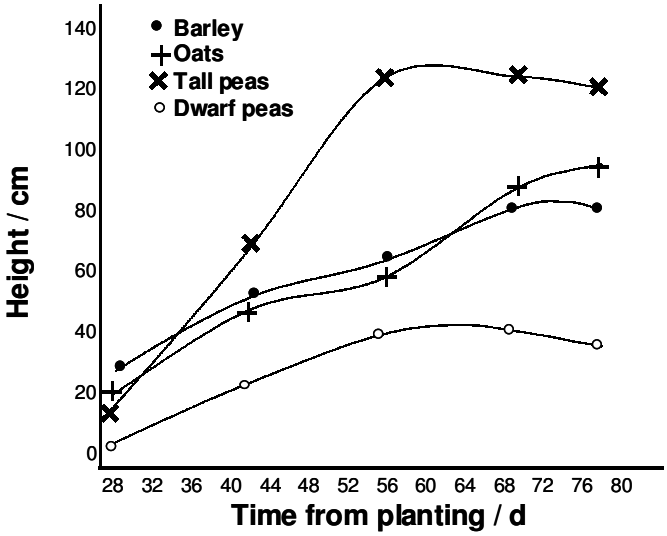


Figure D1 Growth in height of barley, oats, and dwarf and tall peas in monoculture. After Baeumer & De Wit (1968).

The computer simulation can be used to study the interaction of any two of the four kinds of plants at different planting densities by selecting the option *in mixtures*. 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^2 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?*

STUDENTS' MANUAL 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.

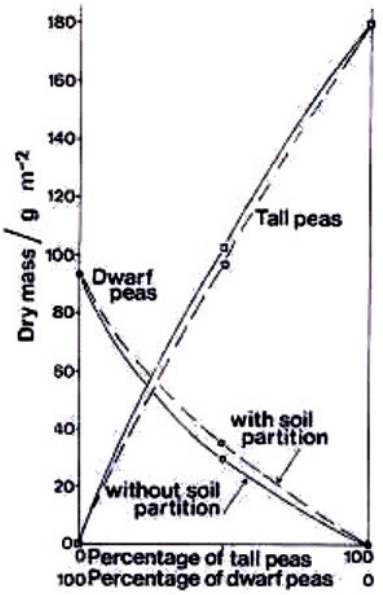


Figure E1 Growth of dwarf and tall peas in monoculture and in mixtures in alternate rows either with or without vertical partitions.

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^{-2}	28.1	27.7	25.7	25.4
Density of clover after 133 days /plants dm^{-2}	26.9	27.2	22.9	5.9
Dry mass of grass after 133 days /g dm^{-2}	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.

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 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 dm-2	27.8	28.3	28.8	25.5	25.0	18.3
Density of clover when mixed with grass plants -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?*