forms of size-frequency distributions seen in fossil populations. It is possible that the programme may also be of use to biologists who may wish to determine the population dynamics of a known animal under different physical and biological conditions, and for this purpose we have included in the output figures the size-frequency and age-frequency distributions of the living population at the end of each quarter year. One experiment will serve as an example. Ten thousand animals recruited evenly over a four-week period during the month of June are grown at a constant increment of 2 units per week, which is in turn subjected to a coefficient of variation of 2. The death rate is constant at 10 per 1,000 per week, but growth is stopped annually for three months from December to February. Graphs of the input-data are shown in Fig. 1.

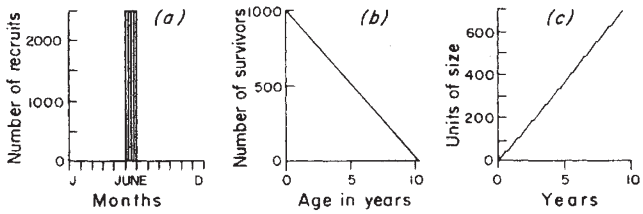

Fig. 1. Graphs of the input data. (*a*) Recruitment of 2,500 animals per week for the four weeks of June. (*b*) Constant death rate of 10 per 1,000 per week. (*c*) Constant growth rate of 2 units per week (growth stopped each year during the three months December–February). This growth rate is subject to a coefficient of variation of 2

The size-frequency distribution of the living population (Fig. 2*a*), as it would be found at the beginning of summer, shows the sharp bursts of yearly recruitment and the effects of mortality. The peaks representing the older recruits gradually merge as a result of the increasing overlap of the size classes. This effect is caused by the coefficient of variation imposed on the growth rate.

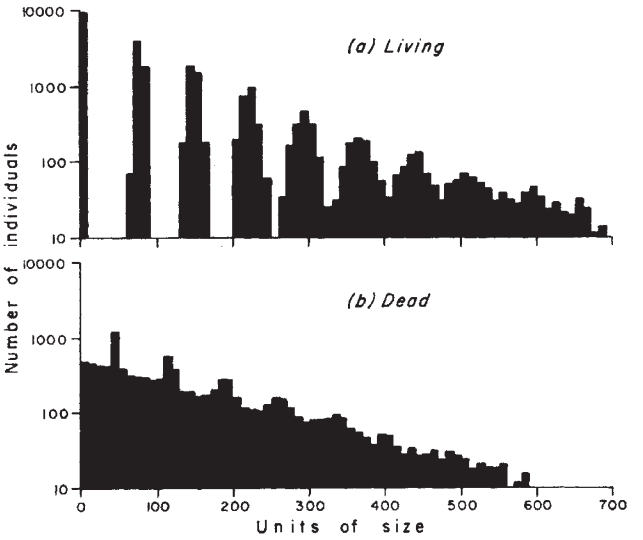

Fig. 2. Size-frequency graphs of (*a*) living and (*b*) resulting dead populations generated by the computer from the information shown in Fig. 1. The irregularity of the largest-size classes in the histograms arises from a 'Monte-Carlo' random-death effect written into the programme. The effect is apparent only with small numbers

The resulting dead population (Fig. 2*b*) also shows a series of peaks, but they represent individuals which died during periods of no growth. These peaks would have been more pronounced had the animals been subjected to increased mortality during the three winter months.

By means of this programme it is possible to generate numerous kinds of living and fossil populations. The number of combinations that may be fed into the computer is obviously very large and we are concerned that our final results should be generally useful and yet compact. If any reader has proposals that may be relevant to the project we would be glad if he would write to one of us.

Access to an '*IBM* 7094' computer without charge has been provided by the Computing Facility of the University of California, Los Angeles.

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[1] Olson, E. C., *J. Geol.*, **65**, 309 (1957).
[2] Craig, G. Y., and Hallam, A., *Palaeontology*, **6**, 731 (1963).

Influence of Herbicides on Respiration of Young *Pinus* Seedlings

FIELD and greenhouse studies with a number of herbicides have demonstrated various degrees of growth inhibition of young gymnosperm seedlings. The effects vary greatly with the chemicals and dosage used, species, age of plants, manner of herbicide application, and environmental conditions[1–4]. Considerable work has been carried out on herbicidal influences on metabolism of herbaceous plants, but very little information is available for the responses of woody plants. Triazine herbicides are generally accepted as inhibitors of photosynthesis[5,6]. Metabolism is probably altered by atrazine in red kidney bean[7] and by simazine in barley roots[8]. The extensive literature on 2,4-*D* and 2,4,5-*T* shows that metabolism varies greatly with species, age of plant, and tissues tested[9–12]. Ingle and Rogers[13] have shown that dalapon may reduce phosphate uptake while it does not alter respiration materially. EPTC causes some increase in respiration of mung beans and corn embryos after relatively long exposure to the herbicide[14]. Experiments have now been extended to evaluate the short-time effects of the active and inert ingredients of commercial formulations of several herbicides on respiration of tissues of woody plants. Herbicides and corresponding commercial formulations were obtained as: 2,4-*D* (esteron 10-10), 2,4,5-*T* (esteron 2,4,5-*OS*), 2,4-DEP (falone 44-*E*), EPTC ('Eptam 6 *E*'), CDEC ('Vegadex'), CDAA ('Randox'), simazine (simazine 50 *W*), atrazine (atrazine 50 *W*), ipazine (ipazine 25 *E*), prometone (prometone 25 *E*), dalapon ('Dowpon'), and sesone (sesone).

Respiration of three-day-old *Pinus resinosa* L. seedlings was determined in a Lardy-type Warburg manometer. The centre well of each vessel contained 0·2 ml. of 20 per cent potassium hydroxide and a piece of filter paper. Each vessel contained 1·0 ml. of 0·1 M acetate buffer (*p*H 4·7) and 1·0 ml. of herbicide suspension. Distilled water was substituted for herbicides in controls. Oxygen uptake was determined at 15-min intervals for 150 min.

At 4,000 p.p.m. of active ingredient, commercial formulations of DCPA, simazine, or sesone had no significant effect on the oxygen uptake of the recently emerged seedlings in a short time period. Dalapon at 4,000 p.p.m. showed a slight inhibitory effect. Atrazine depressed respiration, but it did not show an inhibitory effect with *p*H 6·5 phosphate buffer. Similar results were found with commercial formulations of 2,4-*D* and 2,4,5-*T*. Herbicides provided commercially as oil forms, including ipazine, prometone, EPTC, CDEC, CDAA, 2,4-DEP, 2,4-*D* and 2,4,5-*T*, all depressed respiration at *p*H 4·7.

The foregoing experiments suggested the possibility of blocking of oxygen supply or of gas diffusion in the Warburg vessels. Experiments were therefore continued to evaluate separately the influence of active and inert ingredients contained in commercial formulations of herbicides. Mixtures of total inert ingredients were used.

Two separate experiments were conducted on effects of inert ingredients alone. In the first of these the dosages of inert ingredients, at concentrations adjusted for 4.000

p.p.m. of active ingredient, were as follows: 2,4-*D* (1,700 p.p.m.), 2,4,5-*T* (2,100 p.p.m.) EPTC (1,300 p.p.m.), CDAA (4,500 p.p.m.), CDEC (4,600 p.p.m.), ipazine (12,000 p.p.m.), prometone (12,000 p.p.m.), and 2,4-DEP (5,100 p.p.m.). This experiment showed that the inert ingredients of 2,4-*D*, 2,4,5-*T*, EPTC, CDEC, and CDAA had no significant effects on oxygen uptake. In contrast, the inert ingredients contained in formulations of ipazine, prometone, and 2,4-DEP markedly inhibited respiration. As emphasized earlier, however, the concentrations of inert ingredients of ipazine and prometone in this experiment were very high.

In the second experiment the effect of inert ingredients was tested at concentrations of 4,000 p.p.m. of the inert ingredient. Hence the dosages of inert ingredients of ipazine, prometone, and 2,4-DEP were lower than in the first experiment, while those of 2,4-*D*, 2,4,5-*T* and EPTC were higher. At 4,000 p.p.m. the inert ingredients of prometone and 2,4-DEP still depressed respiration, but the inhibition was lowered. EPTC inert ingredients also significantly decreased respiration at 4,000 p.p.m. Inert ingredients of 2,4-*D* also depressed respiration in short-time experiments, while those of 2,4,5-*T* apparently delayed the effect.

These experiments emphasized that metabolism is altered to varying degrees by either active or inert ingredients of commercial herbicide formulations. In summary, respiration was inhibited primarily by the active ingredients of 2,4-*D*, 2,4,5-*T*, EPTC, CDEC, and CDAA and by the inert ingredients of prometone, and ipazine formulations. There may also have been an interactive effect of inert and active ingredients of CDEC and CDAA. Further experiments are needed to evaluate these possible interactions.

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1 Kozlowski, T. T., and Kuntz, J. E., *Soil Sci.*, **95**, 164 (1963).
2 Winget, C. H., Kozlowski, T. T., and Kuntz, J. E., *Weeds*, **11**, 87 (1963).
3 Kozlowski, T. T., *Nature*, **205**, 104 (1965).
4 Sasaki, S., and Kozlowski, T. T., *Univ. Wisconsin, Forestry Res. Note* 105 (1963).
5 Gysin, H., *Chem. and Indust.*, 1393 (1962).
6 Hilton, J. L., Jansen, L. L., and Hull, H. M., *Ann. Revs. Plant. Physiol.*, **14**, 353 (1963).
7 Ashton, F. M., and Uribe, E. G., *Weeds*, **10**, 295 (1962).
8 Allen, S. W., and Palmer, R. D., *Weeds*, **11**, 27 (1963).
9 Bourke, J. B., Fang, S. E., and Butts, J. S., *Plant Physiol.*, **37**, 233 (1962).
10 Dalrymple, A. V., and Basler, E., *Weeds*, **11**, 41 (1963).
11 Kelly, S. M., and Avery, G. S., *Amer. J. Bot.*, **36**, 421 (1949).
12 Key, J. L., Hanson, J. B., and Bils, R. F., *Plant Physiol.*, **35**, 177 (1960).
13 Ingle, M., and Rogers, B. J., *Weeds*, **9**, 264 (1960).
14 Ashton, F. M., *Weeds*, **11**, 295 (1963).

Effects of Seed Germination-stimulants on the Witchweed *Striga euphrasioides* (Vahl) Benth.

PARASITISM in some species of *Striga* has often been questioned. According to Williams[1] *S. euphrasioides* is one of the unlikely exceptions to the group of obligate parasitic species. It was, therefore, felt desirable to investigate its seed germination and compare it with similar investigations on certain species of *Striga* and *Orobanche* that are recognized as root parasites.

Stock collections of seeds were made from mature dry capsules of several plants. For each experiment seeds were removed from the stock in two batches and one of them was washed in running tap water for 48 h. Both batches of seeds were surface-sterilized in chlorine water for 10 min and sown on agar nutrient media (*p*H 5·8). A modified White's medium[2] containing 4 per cent sucrose and 1 p.p.m. indole-3-acetic acid served as basal medium. The effects of gibberellic acid and kinetin on germination

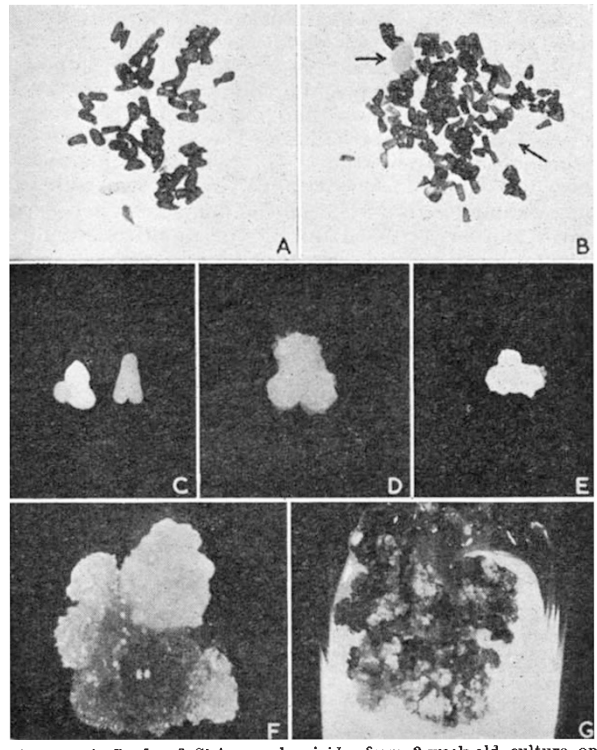

Fig. 1. *A*, Seeds of *Striga euphrasioides* from 3-week-old culture on modified White's medium (WM) (×*c.* 7); *B*, seeds from 2-week-old culture on WM+10 p.p.m. kinetin; two seeds show emergence of embryos (arrow-marked) (×*c.* 5); *C*, embryos removed from 12-day-old culture on WM+10 p.p.m. kinetin (×*c.* 10); *D*, embryo from 24-day-old culture showing proliferation (×*c.* 9); *E*, 5-week-old culture of proliferating embryo on WM supplemented with 10 p.p.m. kinetin (×*c.* 8); *F* and *G*, 5-week-old and 3-month-old cultures of embryo calli on WM supplemented with 400 p.p.m. casein hydrolysate +15 per cent coconut milk (*F*, ×*c.* 8; *G*, ×*c.* 0·9)

were investigated. For each treatment thirty-six cultures were raised in two replicates. Half the number of cultures were grown in diffuse daylight (8–10 ft.-candles) and the other half in the dark.

Unwashed seeds failed to germinate under any experimental conditions. Germination of water-washed seeds was helped by daylight. In subsequent experiments, therefore, only washed seeds were used and incubation in the dark was abandoned.

On the basal medium water-washed seeds lay dormant up to 6 weeks after sowing (Fig. 1*A*). Addition of 5, 10 or 12·5 p.p.m. gibberellic acid to the medium did not help in overcoming dormancy. If, however, the medium was supplemented with 10 p.p.m. kinetin the testa in some of the seeds ruptured within 10–12 days after sowing and the embryos were completely released (Fig. 1*B*). Four days later, root hairs appeared on the elongated radicle. About 18–20 days after sowing the cotyledons formed a callus tissue (Fig. 1*C*, *D*).

With a view to inducing organ formation the proliferated embryos were transferred to media supplemented with one or more of the following substances: kinetin, casein hydrolysate and coconut milk. In treatments with 10 p.p.m. kinetin no organs developed (Fig. 1*E*). Individually as well as in concert, both 400 p.p.m. casein hydrolysate and 15 per cent coconut milk elicited the best growth of the callus tissue. It formed several new mounds along its periphery and grew into a nodulated mass (Fig. 1*F*, *G*). However, shoot-buds did not develop in cultures. A similar response to kinetin treatment was also shown for *Striga asiatica*[3]. Presumably, exogenous factor(s) other than kinetin may be required for shoot morphogenesis. In *Orobanche hederae*, for example, contact with the root of its host, *Hedera helix*, was indispensable for the initiation of shoots[4]. Contrarily, in *Orobanche aegyptiaca* shoot apices differentiated *in vitro* in the absence of any host plants[5].