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# Effects of nitrogen fertilizer applied to seed crops on seed yields and regrowth of progeny tubers in potatoes

BY P. J. O'BRIEN* AND E. J. ALLEN*

*Department of Agriculture (Crop Husbandry), University College of Wales, Aberystwyth, Dyfed*

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SUMMARY

Three experiments, carried out in 3 years (1972–5), which examined the effects of a wide range of rates of nitrogen fertilizer applied to seed crops of Home Guard on seed and progeny crop growth are reported. There was little effect of increasing rate of N application over the range 0–300 kg/ha on seed yield, and the results suggested that very low rates of nitrogen fertilizer ( < 75 kg/ha) were required for maximum seed yield in mid-Wales. Increasing the rate of nitrogen fertilizer above 304 kg/ha delayed growth and decreased yield in seed crops. Although increasing the rate of nitrogen fertilizer in seed crops delayed senescence and increased the nitrogen concentration of tubers, there were few consistent effects on sprouting or growth of progeny crops.

Close negatively quadratic relationships were found between the dry-matter content of tubers and their size. The dry-matter content of all sizes of tubers increased during growth, but there were no effects of nitrogen on dry-matter content.

## INTRODUCTION

The application of nitrogen (N) fertilizer to potatoes affects leaf growth, onset and duration of tuber growth and chemical composition of the progeny tubers (Werner, 1934; Thow, 1970; Dyson & Watson, 1971). Variation in onset of tuber growth affects the chronological age of the tuber, which has been reported to influence its productivity (Kawakami, 1952) and the tuber content of various nutrients has also been reported to affect regrowth of tubers (Headford, 1961; Dinkel, 1968; Schepers, Hoogland & Krijthe, 1969; Walker, 1974). Thus, rate of N application to seed crops may affect seed crop yield and regrowth of progeny tubers. Unfortunately, several experiments studying effects of N application rates for seed crops have used very high rates, which are clearly uneconomic as they greatly exceed reported optimum N rates for seed yields (e.g. Schepers *et al.* 1969). The importance of effects over the likely economic range of application rates remains largely unknown. In order to establish the causes of any effects of N applications to seed crops it is essential to use several rates of application and to measure effects on seed crop growth, tuber nutrient concentration and tuber regrowth as the ware potato crop. The reported experiments were carried out in this way for three consecutive seed and ware crops using the early potato variety, Home Guard.

* Present address: Department of Applied Biology, University of Cambridge, Pembroke Street, Cambridge, CB2 3DX.

## THE EXPERIMENTS

*Seed crops*

The seed crops were grown on the farm of Mr A. Lewis, Cefnceido, Rhayader, Powys on freely draining slaty mudstone and siltstone soils of the Denbigh Association (Soil Survey of England and Wales, 1984) in 1972–4. The methods of husbandry were essentially as reported for the Rhayader site of a previous paper (O'Brien & Allen, 1986). The application rates, dates of defoliation and seed production details are shown in Table 1. N was applied by hand to opened ridges before planting in all experiments and, in Expts 1 and 2, the second application of the treatment in which N was divided into two dressings was 1 week after the commencement of tuber initiation. All three experiments received a basal dressing of 65 kg P and 127 kg K/ha just prior to planting and approximately 40 t/ha of farmyard manure was applied in the preceding winter to the site of Expt 3. In all 3 years potatoes followed long-term leys. In Expts 1 and 2 each N treatment occupied an area of 40 $m^2$ and samples for measuring seed yields were taken

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Table 1. *Details of seed crop treatments and production* 1972–4

| Experiment | Seed year | Rate of N fertilizer application (kg/ha) | Date of defoliation | Seed size | Date of planting | Within-row spacing (cm) |
|---|---|---|---|---|---|---|
| 1 | 1972 | 0, 152*, 152 | 17. vii; 1. viii; 15. viii; 29. viii | 35–55 mm | 1. v | 15 |
| 2 | 1973 | 0, 76, 152; 152*, 228 | 11. vii; 25. vii; 8. viii; 21. viii | 80 ± 15 g | 19. iv | 20 |
| 3 | 1974 | 0, 76, 152, 304, 608 | 8. vii; 5. viii; 3. ix | 80 ± 15 g | 9. v | 20 |

* Divided application.

Table 2. *Details of ware production* 1973–5

| Experiment | Ware year | Seed size | Date of planting | Date of sampling for (a) growth analysis (2 plants/plot) | Date of sampling for (b) tuber yield estimate | Plot size |
|---|---|---|---|---|---|---|
| 1 | 1973 | 38–51 mm | 15. iii | 17. v; 14. vi; 27. vi | 14. vi; 27. vi; 24. vii | 5 rows wide; 3·05 m long |
| 2 | 1974 | 50 ± 5 g<br>62·5 ± 7·5 g | 22. iii | 25. v; 10. vi; 23. vi | 25. v; 10. vi; 23. vi | 7 rows wide; 2·86 m long |
| 3 | 1975 | 50 ± 5 g<br>62·5 ± 7·5 g | 22. iii | 26. v; 9. vi; 23. vi | 26. v; 9. vi; 23. vi | 7 rows wide; 3·3 m long |

only in Expt 2. In Expt 3 (1974) the five rates of N application were arranged in a randomized-block design with four replicates. Plots consisted of five rows (76 cm apart) and 2·86 m long. Sampling for detailed growth analysis was carried out on 7 and 25 June, 8 July, 5 August and 3 September. Seed yield was recorded from 2·5 m lengths of row in all replicates after defoliation on the last three dates of sampling. All harvesting was carried out within a week of defoliation. Tubers from all replicates of each treatment were bulked after each harvest and then selected and used for the ware phase of the experiment. Results of experiments on timing of defoliation and harvesting by P. J. O'Brien, J. L. Jones and E. J. Allen (unpublished) provided no evidence that the short intervals from defoliation to harvesting influenced the effects of N fertilizers.

### *Ware crops*

The experiments were carried out at the University College of Wales Field Station at Trefloyne near Tenby on Devonian Sandstone soils of the Milford Association (Soil Survey of England and Wales, 1984). In the first experiment (1972–3) the seed crop treatments were combined with two storage temperatures (8 and 13 °C) in a factorial design with two replications. In the two following experiments all seed was stored in a glasshouse at 8–9 °C for the whole storage period, and these experiments were single replicates of the combination of factors detailed in Tables 1 and 2 with size of seed confounded with blocks which contained all other combinations. There was no interaction between seed size and any other factor, but the 'error' term in the analysis of variance is likely to be greater than that in the analysis of an orthodox randomized-block design of the same seed size. Methods of analysis of the data have been discussed by O'Brien & Allen (1986). In all experiments, fertilizer dressings of 152 kg N, 65 kg P and 160 kg K/ha were spread over the ridges prior to hand planting. The details of dates of planting and sampling, plot sizes and general husbandry are given in Table 2. The experiments were planted close to those reported in earlier papers (O'Brien & Allen, 1986; P. J. O'Brien, J. L. Jones and E. J. Allen, unpublished) and were generally treated in a similar way.

## RESULTS

The effects of N applied to seed crops on both seed and ware crops were similar in the 3 years, and are mainly illustrated by the more extensive results of Expt 3. The divided applications of N produced similar effects to a single application of the same

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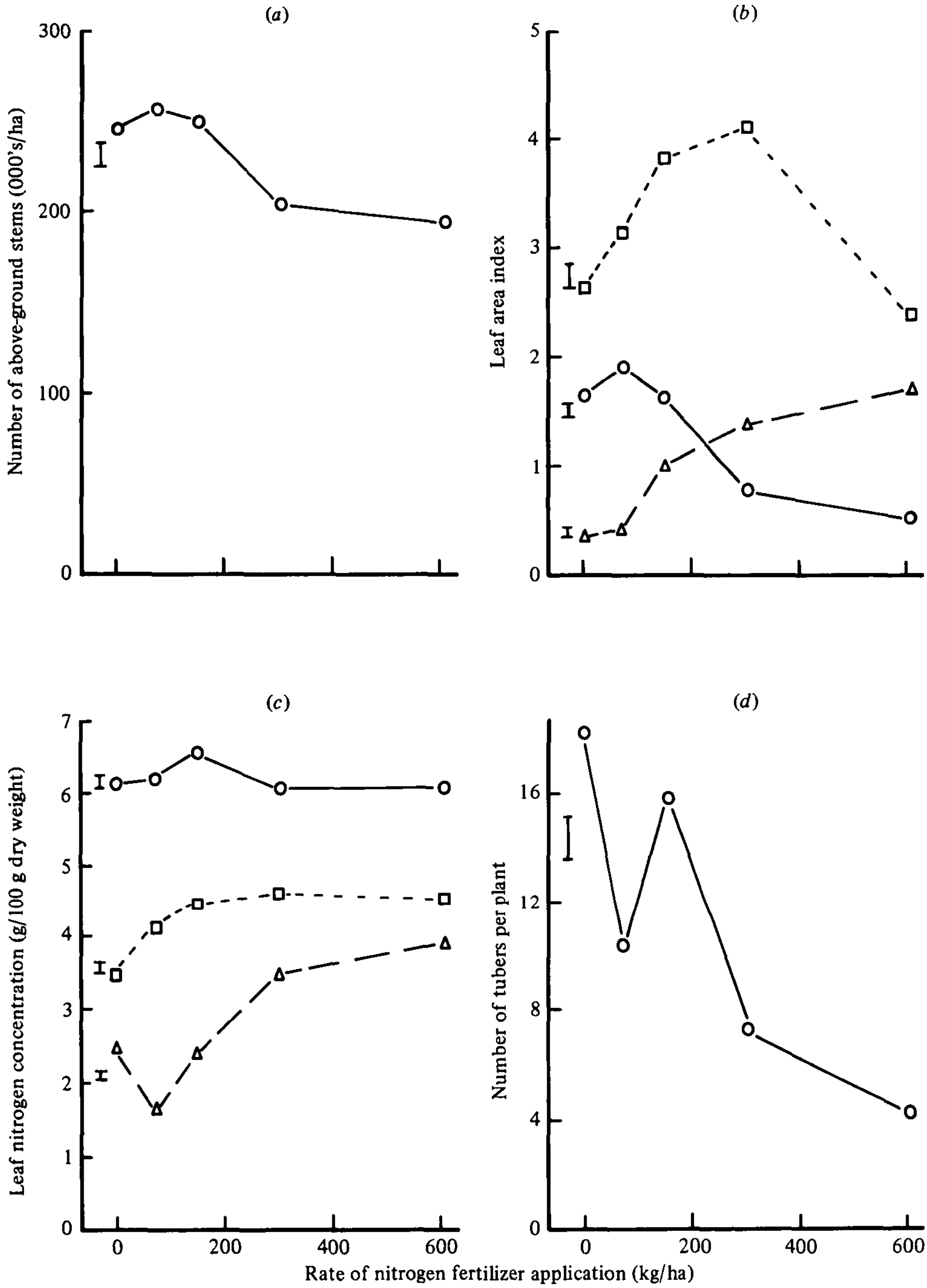


**Fig. 1.** Effect of rate of nitrogen fertilizer application on (*a*) number of above-ground stems, (*b*) leaf area index, (*c*) leaf nitrogen concentration and (*d*) number of tubers per plant in the seed crop of Home Guard in 1974 (Expt 3). (*a*) ○—○, 16. vii; (*b*) ○—○, 20. vi; □---□, 8. viii; △——△, 3. ix; (*c*) ○—○, 20. vi; □---□, 8. viii; △——△, 3. ix; (*d*) ○—○, 7. vi. I, S.E.

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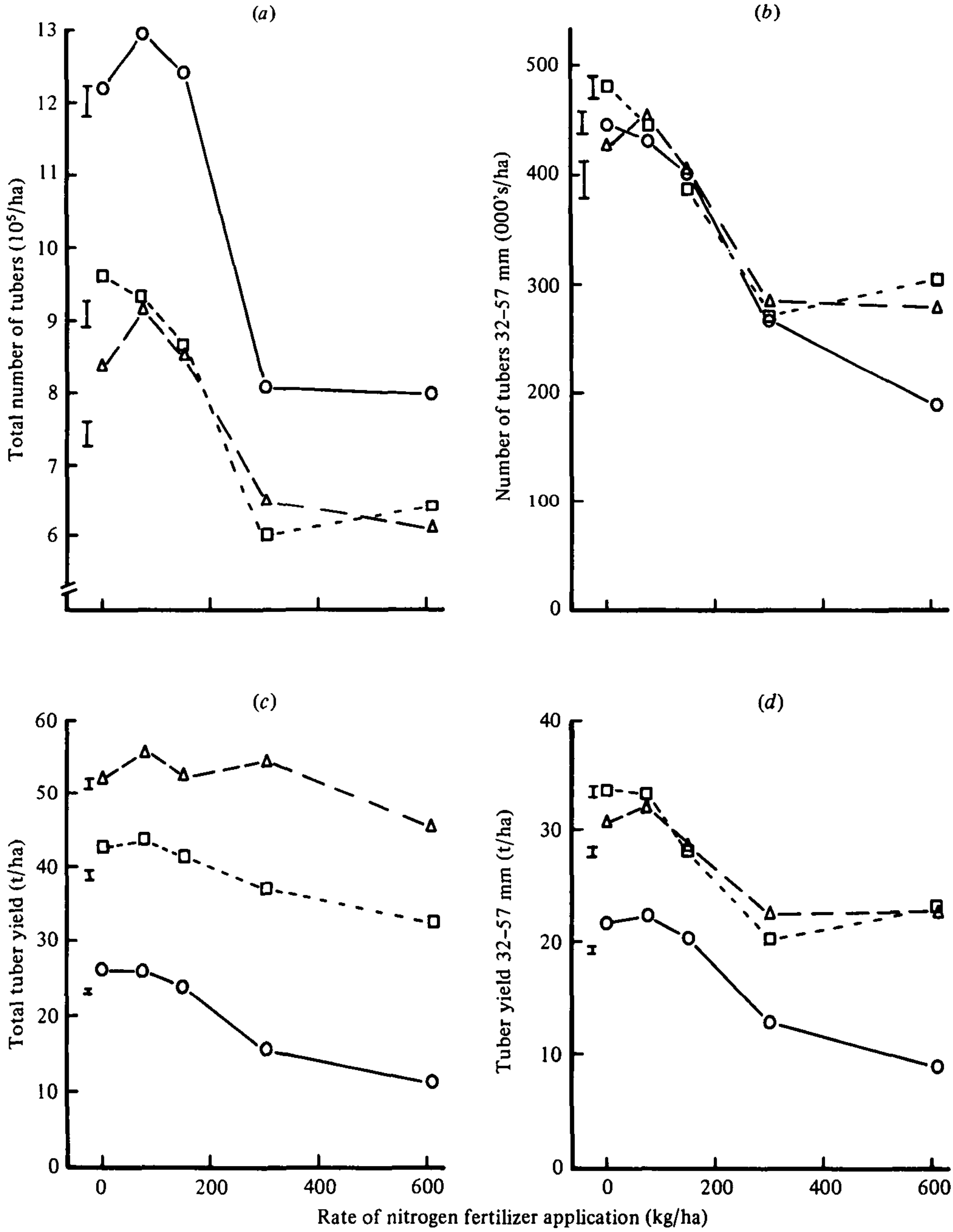


**Fig. 2.** Effect of rate of nitrogen fertilizer application on (*a*) total number of tubers, (*b*) number of tubers 32–57 mm, (*c*) total tuber yield and (*d*) tuber yield 32–57 mm at three defoliation dates of the seed crops of Home Guard in 1974 (Expt 3). ○—○, 8.vii; □- - -□, 5.viii; △— —△, 3.ix. I, S.E.

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total amount made at planting and are not considered separately. The full results are available in thesis form (O'Brien, 1981). The dry-matter, nitrogen, phosphorus and potassium concentration of tubers from seven size grades were measured at three harvest dates in the seed crop of Expt 3. The data were analysed by regression analysis of the dry-matter content and nutrient concentration on tuber size using an orthogonal polynomial technique, described by Wurr & Allen (1974). Predicted values were obtained from the analyses, and the effects of nitrogen fertilizer applied to the seed crop on dry-matter content and nutrient concentration of tubers are presented as fitted lines.

### *Seed crops*

#### *Emergence and leaf growth*

Very high rates of N (304 and 608 kg/ha) delayed plant emergence and produced fewer above-ground stems than lower applications (Fig. 1*a*). Applications up to 152 kg N/ha had little effect on number of stems at any stage of growth in any experiment. Increasing N application rates above 76 kg/ha reduced leaf area index (L) early in growth, but as growth continued the amount of N producing the highest leaf area index increased (Fig. 1*b*). Thus, at the end of growth when L values were low, L increased over the whole range of N rates. Peak values of L were high in mid-season even with no nitrogen, and the leaf surface persisted well for a variety which is frequently regarded as short-lived.

#### *N concentration of leaves*

With delay in sampling, N concentration of leaf dry matter decreased markedly at all rates of nitrogen (Fig. 1*c*). There was no effect of rate of N on leaf N concentration at the first sampling, but at succeeding samples increasing the rate to 152, then 304 and finally 608 kg/ha increased N concentration of leaves. Thus, at final harvest, the highest rate of N produced the largest leaf area with the highest N concentration.

Foliar yellowing as a consequence of increasing senescence always occurred earlier at the lower rates of N (0 and 76 kg/ha), although differences were much smaller in Expts 1 and 2 than in Expt 3.

#### *Number of tubers*

Weekly observations from plants in discard rows showed that tuber initiation was later, and fewer tubers were set from the two highest rates of nitrogen (Fig. 1*d*). Increasing the rate of N up to 152 kg/ha had no effect on total number, or number of tubers of seed size. The two highest rates of N reduced the total number and number of tubers of seed size throughout growth (Fig. 2).

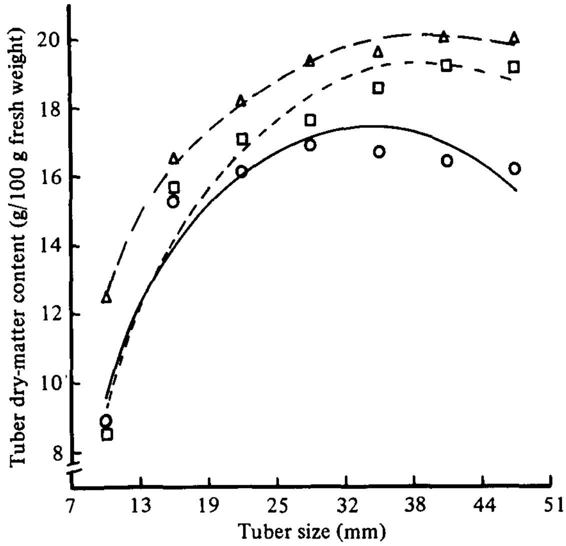


Fig. 3. Relationships between the dry-matter content of tubers and their size at three dates of defoliation of the seed of Home Guard in 1974 (Expt 3). ○—○, 8. vii; □---□, 5. viii; △——△, 3. ix.

#### *Yield of tubers*

Increasing the rate of nitrogen above 152 kg/ha substantially reduced total yield at the first two harvests and yield of seed-size tubers at all harvests (Fig. 2). At the two latest harvests the decreases in yield of seed-size tubers at the two highest rates of N were much greater than for total yield. These high rates produced more larger (> 57 mm) tubers and, therefore, a relatively smaller proportion of their tubers in the seed fraction than the lower rates of N. Increasing the rate of N up to 152 kg/ha slightly decreased yield of seed-size tubers at all harvests. Similar effects were found in Expt 2, and the results suggest for the conditions of these experiments optimum rates of N for seed yields of no more than 76 kg/ha for harvests after July and little need for any N for harvests in July.

#### *Chemical composition of tubers*

*Dry-matter content.* At all dates of defoliation, significant negatively quadratic relationships between dry-matter content and increasing tuber size were found (Fig. 3). At each defoliation, dry-matter content markedly increased with the first two increments in tuber size, but then increased progressively more slowly with further increase in tuber size. There was no interaction between size and either date of defoliation or rate of N. The dry-matter content of all tuber sizes

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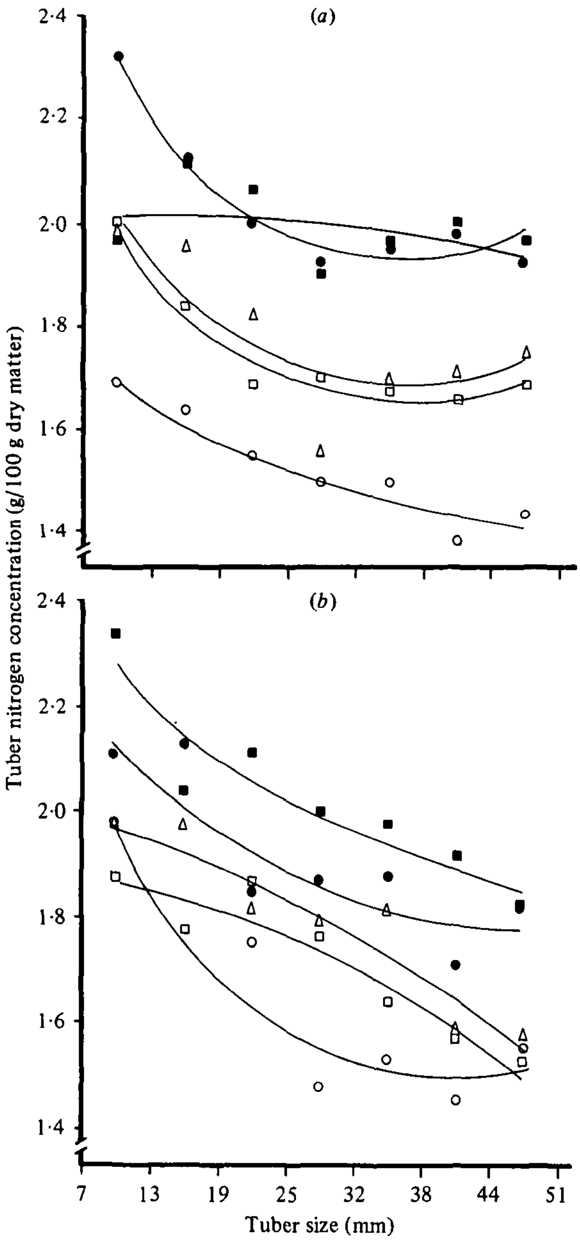


Fig. 4. Relationships between the rate of nitrogen fertilizer application and nitrogen concentration of tubers in different size grades at two dates of defoliation of the seed crop of Home Guard in 1974 (Expt 3). Dates of defoliation (*a*) 8. vii; (*b*) 3. ix. Rate of nitrogen application (kg/ha) ○, zero; □, 76; △, 152; ●, 304; ■, 608.

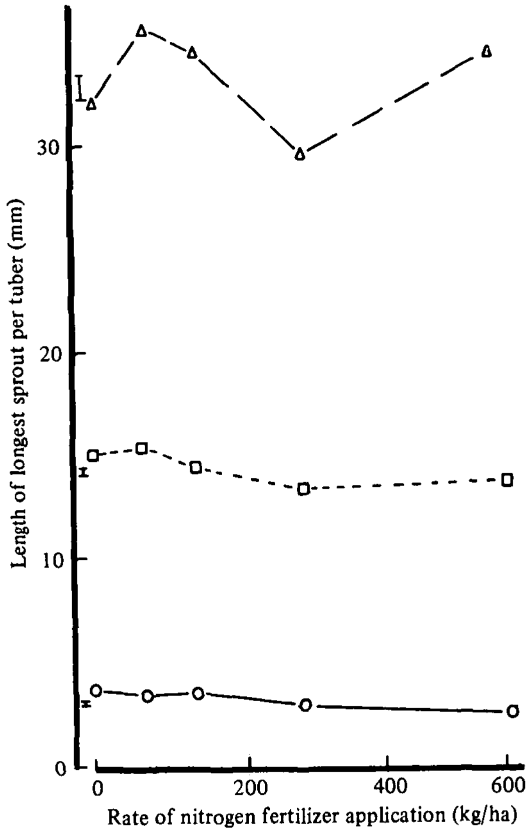


Fig. 5. Effect of rate of nitrogen fertilizer application on the length of the longest sprout per tuber during storage of Home Guard (Expt 3). ○—○, 6. xi; □---□, 2. i; △——△, 26. ii.

increased with delay in defoliation, but N had no effect on dry-matter content of any tuber size.

*N concentration*. Significant positively quadratic relationships between N concentration of tubers and their size were found at all dates of defoliation (Fig. 4). There was no interaction between tuber size and date of defoliation or rate of N. The rate of N did not affect the type of relationship between tuber N concentration and size, but significantly increased the N concentration of all tuber sizes. The N concentration of seed-size tubers was substantially increased by the low rates of N (76 and 152 kg/ha) and further increased by higher rates. Date of defoliation had only small effects on N concentration of tubers.

### *Ware crops*

*Dormancy and sprout growth*

The effects of N application to the seed crop on the length of the dormant period are shown for all experiments in Table 3. In Expt 1 increasing the rate of N from 0 to 152 kg/ha shortened the dormant period, but in Expt 2, in which effects of N on foliage senescence were also small, increasing the rate of N from 0 to 228 kg/ha had no effect on

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**Table 3.** *Effect of rate of nitrogen fertilizer application on the number of days from harvesting to onset of sprout growth (averaged over defoliation dates) of Home Guard in 3 years*

| Experiment | Year | Rate of nitrogen fertilizer application (kg N/ha) 0 | 76 | 152 | 152* | 228 | 304 | 608 | S.E. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1972 | 63 | — | 60 | 59 | — | — | — | 0·87 |
| 2 | 1973 | 77 | 77 | 76 | 74 | 76 | — | — | 1·07 |
| 3 | 1974 | 71 | 74 | 74 | — | — | 81 | 83 | 2·02 |

* Divided application: half at planting, half at tuber initiation.

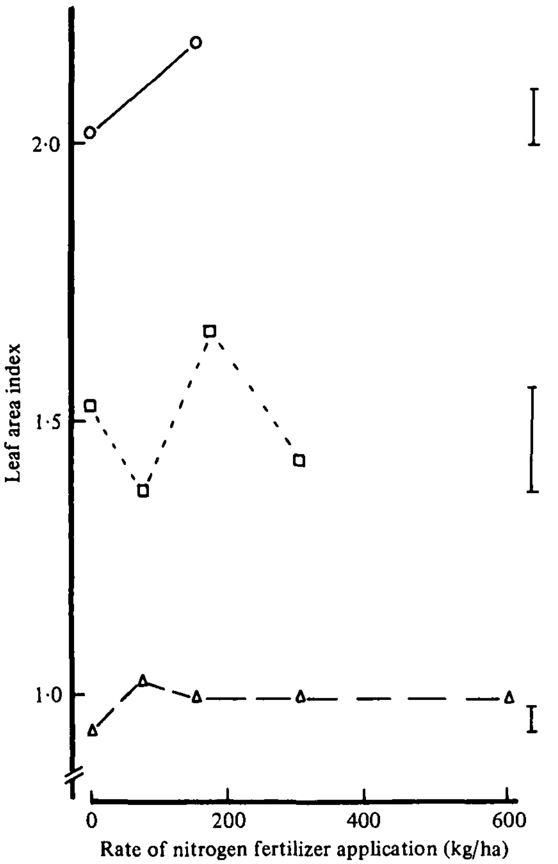


Fig. 6. Effect of rate of nitrogen fertilizer application on maximum leaf area index in progeny crop of Home Guard in 3 years. ○—○, 14. vi. 73; □---□, 10. vi. 74; △——△, 9. vi. 75. I, S.E.

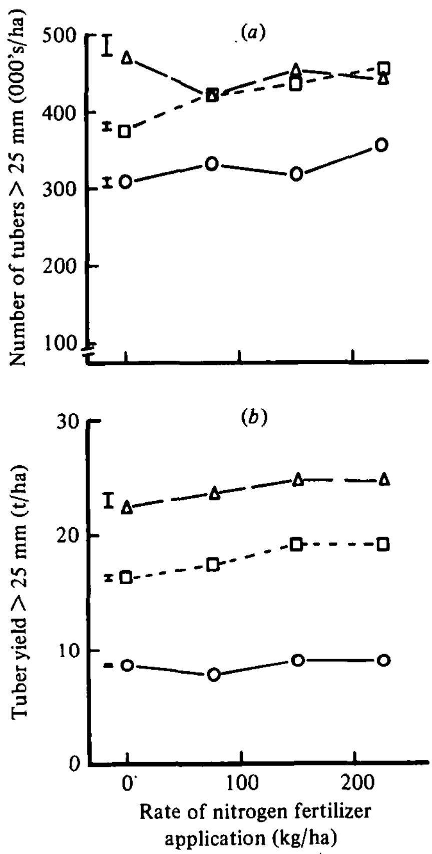


Fig. 7. Effect of rate of nitrogen fertilizer application on (*a*) number of tubers > 25 mm and (*b*) tuber yields > 25 mm in the progeny crop of Home Guard at three dates of harvest in 1974 (Expt 2). ○—○, 25. v; □---□, 10. vi; △——△, 23. vi.

the duration of dormancy. In Expt 3 increasing the rate of N especially to the highest rates lengthened the dormant period. The results provide no support for the suggestions either that tuber N concentration is a major influence on the duration of dormancy or that foliage senescence is of any significance. The effects of N applications to seed crops on the ending of dormancy were always small in magnitude and represented only a marginal alteration to the period of sprout growth in Home Guard, which has a relatively short dormant period. In Expt 3 the effects on the ending of dormancy were reflected in the length of longest sprout throughout sprouting (Fig. 5). There was no effect of N applications to seed crops on either number of sprouts or any aspect of sprout morphology in any experiment.

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*Field growth*

In all experiments there was no effect of N application to seed crops on emergence, number of mainstems or secondary stems or leaf area index (L). Overall, leaf area indices were low, and complete ground cover was not achieved. Leaf area index was also lower in Expts 2 and 3 than in Expt 1 (Fig. 6). The restricted canopy development in Expts 2 and 3 was probably largely due to the effects of a late frost (6 May) in 1974 which damaged the foliage, and a prolonged period of low temperatures after planting in 1975.

Only in Expt 2 were effects of N applied to seed crops found on number of tubers. In this experiment the rate of N applied to the seed crop increased the total number of tubers and the number > 25 mm in the progeny crop at the second harvest (Fig. 7). Collectively, however, the results show little effect of seed crop N on number of tubers in the progeny crop. There was no effect of seed crop N on tuber yields of the progeny crop in Expts 1 and 3, but in Expt 2 increasing the rate of N application slightly increased tuber yields at all dates of harvest and the effect was significant at the second harvest (Fig. 7).

## DISCUSSION

The sites used for these experiments were probably high in soil N following the application of farmyard manure to a long ley, but they were typical of sites used for seed multiplication in Wales and in upland areas elsewhere. On the free-draining soils of these experiments any effects of rate of N application to seed crops on regrowth of progeny tubers were always small and infrequent over all experiments. There were large effects on tuber N concentrations, but in most cases this was not associated with any effect on growth and yield. The small positive effects of nitrogen applied to the seed crops on ware yields in Expt 2 were associated with small increases in number of above-ground stems, but the effects did not occur in similar seed in the other two years. Thus, any beneficial effect of increasing the rate of N applied to the seed crop appeared to be small and inconsistent and of no commercial potential for seed producers.

The general absence of effects of seed tuber N content on ware crop growth may be attributed to adequate N applications to the ware crop. Although some authors (Thow, 1970, 1981) have argued the importance of tuber N reserves in early crop growth, there is little evidence of a significant nutrient contribution from the mother tuber to early growth of field crops, and the evidence from the reported experiments does not suggest that growth is greatly influenced by seed tuber N contents.

The effects of rate of N application to seed crops on the growth and yield of the seed crop itself were more interesting and important than those found in the succeeding ware crop. The very high rates of N markedly delayed emergence and decreased crop growth for the early part of the season. This resulted in a reduced number of tubers and effects on size grading at the end of the season. The likely range of application rates in practice should not exceed 300 kg/ha for any potato crops as there is no evidence of yield responses to such levels, but such rates are probably in use as rates of up to 250 kg/ha have been recommended for seed crops (Saunders, 1979) and the national average application rate for N for maincrops in 1983 was 202 kg/ha (Church, 1984). Thus the results for the 304 kg/ha application may have practical implications. There were only small effects on yields of applying up to 150 kg N/ha to seed crops. It was expected that seed crops grown in a relatively moist environment on sites following grazed grass would show relatively small responses to applied N. However, the data suggest little or no N is required in such circumstances for maximum seed yield, and few growers use so little.

Although increasing N application rates increased tuber N concentrations there was no effect on dry-matter content of individual tuber sizes. Thus the conflicting reports in the literature regarding the effects of N on dry-matter content are probably associated with effects of N on tuber-size distribution and the use of a large range of sizes in the samples used for dry-matter determinations (Schippers, 1968). Tuber size had a large effect on dry-matter content, and the negatively quadratic relationships were similar to those reported by Ifenkwe, Allen & Wurr (1974) and Wurr, Bean & Allen (1978). The results also showed that dry-matter content increased throughout growth, while Wurr *et al.* (1978) and Ifenkwe & Allen (1983) found that dry-matter content decreased late in growth. The direction of change and the tuber size giving maximum dry-matter content can change during growth, and the significance of these effects has not been widely appreciated. There is a need for greater understanding of the causal factors in these effects, for their significance in crops for processing is considerable. Such crops are frequently allowed to grow into the autumn in order to improve and increase their dry-matter contents, a practice which may be ineffective or produce the opposite effect.

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## REFERENCES

CHURCH, B. M. (1984). Use of fertilizers in England and Wales, 1984. *Rothamsted Experimental Station, Report for* 1983, pp. 295–300.

DINKEL, D. H. (1968). Nitrogen metabolism of potato tubers; assimilation of stored tuber reserves in the light and dark. *Proceedings of the American Society of Horticultural Science* **93**, 476–484.

DYSON, P. W. & WATSON, D. J. (1971). An analysis of the effects of nutrient supply on the growth of the potato crop. *Annals of Applied Biology* **69**, 47–63.

HEADFORD, D. W. (1961). Sprout growth of the potato. Ph.D. thesis, University of Nottingham.

IFENKWE, O. P. & ALLEN, E. J. (1983). Nitrogen and potassium uptake by high yielding potato crops. *Journal of Agricultural Science, Cambridge* **101**, 103–111.

IFENKWE, O. P., ALLEN, E. J. & WURR, D. C. E. (1974). Factors affecting the relationship between tuber size and dry-matter content. *American Potato Journal* **51** (7), 233–242.

KAWAKAMI, K. (1952). Physiological aspects of potato seed tubers. *Memoirs of the Hyogo University of Agriculture* **2**, 1–14.

O'BRIEN, P. J. (1981). Effects of seed crop treatments on the growth and yield of progeny tubers of early cultivars. Ph.D. thesis, University College of Wales, Aberystwyth.

O'BRIEN, P. J. & ALLEN, E. J. (1986). Effects of site of seed production on seed yields and regrowth of progeny tubers in potatoes. *Journal of Agricultural Science, Cambridge* **107**, 83–101.

SAUNDERS, A. R. (1979). Maximizing seed and ware potato yields. 3. Growing the seed crop. *Agriculture in Northern Ireland* **54**, 18–20.

SCHEPERS, A., HOOGLAND, R. F. & KRIJTHE, N. (1969). Influence of NPK application to seed potato crops on the productivity of the progeny. *European Potato Journal* **12** (4), 251–263.

SCHIPPERS, P. A. (1968). The influence of rates of nitrogen and potassium application on the yield and specific gravity of four potato varieties. *European Potato Journal* **11** (1), 23–33.

SOIL SURVEY OF ENGLAND AND WALES (1984). *Soils of England and Wales Bulletin No.* 11. Soil Survey Unit, Rothamsted, Harpenden.

THOW, R. F. (1970). Second-generation effects of N, P and K on the potato. Ph.D. thesis, University of Edinburgh.

THOW, R. F. (1981). The effects of plant population, N fertilizer rate and variety on the development and yield of potatoes. *Proceedings of the 8th Triennial Conference of the European Association for Potato Research, Munich*, pp. 52–53.

WALKER, M. G. (1974). Mineral nutrition and progeny performance in potatoes. *The Royal Society of New Zealand, Bulletin No.* 12, pp. 917–922.

WERNER, H. O. (1934). The effect of controlled nitrogen supply with different temperatures and photoperiods upon the development of the potato plant. *Nebraska Agricultural Experimental Station Research Bulletin* **75**, 1–32.

WURR, D. C. E. & ALLEN, E. J. (1974). Some effects of planting density and variety on the relationship between tuber size and tuber dry-matter percentage in potatoes. *Journal of Agricultural Science, Cambridge* **82**, 277–282.

WURR, D. C. E., BEAN, J. N. & ALLEN, E. J. (1978). Effects of variety and date of harvest on the tuber dry-matter percentage of potatoes. *Journal of Agricultural Science, Cambridge* **90**, 597–604.

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