INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
1560–8530/2004/06–3–458–461
http://www.ijab.org

Aerial Growth and Dry Matter Production of Potato (*Solanum tuberosum* L.) cv. Desiree in Relation to Phosphorus Application

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ABSTRACT

The growth of potato cv. Desiree in relation to phosphorus fertilizer application was studied at the Morfa Mawr Field Research Station, University of Wales, Aberystwyth, UK during 1995. The sprouted seed tubers were planted on ridges prepared 70 cm apart, at a distance of 28 cm. Six different levels of phosphorus fertilizer (i.e. 0, 50, 100, 200, 300 and 400 kg P_2O_5 ha^{-1}) were applied to the crop by mixing in the soil before planting. The aim of the present study was to obtain some basic information on growth responses of potato to phosphate application and to determine the distribution of phosphorus within plants. Results indicated that there were significant differences in ground cover percentage and leaf area index (L) among different phosphorus levels applied, at early harvest dates. Phosphorus uptake by plants in different treatments also differed significantly at some harvest dates.

Key Words: Dry matter production; Leaf area index; Phosphate; P uptake

INTRODUCTION

No other major arable crop receives as large an application of phosphate fertilizers as potatoes and, therefore, the spotlight must fall on this crop as a candidate for more efficient P fertilizer use. One of the major problems in the use of phosphate fertilizer is the fixation of applied phosphate by the soil and however, the efficiency of P uptake from fertilizer is low (Ali, 1998). The mechanism of this fixation process has been the subject of a great deal of study by soil chemists. Soluble phosphate applied to the soil loses its solubility almost immediately on coming in contact with the soil, as a result its availability to the planted crop is greatly reduced (Jenkins & Ali, 2000; Ali *et al*., 2004). Phosphorus deficient plants are characterized by stunted growth, dark green leaves with a leathery texture, and reddish purple leaf tips and margins (Tucker, 1999).

Phosphorus application affects crop growth by increasing radiation interception (over the whole season) or by increasing light use efficiency. The former is likely to be more important than the latter, therefore enhancing canopy growth becomes more important. Similarly, Westermann and Kleinkopf (1985) reported that plant nutrient concentrations and uptake rates play a major role in maintaining a plant top which leads to increased tuber yields. Soltanpour and Cole (1978) found that application of N and P fertilizers increased leaf, stem and tuber growth rates and, consequently yields. Similar other studies have shown that the phosphorus content in petiole decreased as the crop advanced in age (Gupta & Saxena, 1976). Plants may therefore be unable to access sufficient soil P during early growth. To overcome this problem in potatoes, the standard practice is to apply large amounts of soluble P just before or at planting to ensure high concentrations of phosphate in soil solution (Ali, 1998).

A large number of scientists have found the relationships between P availability and potato growth (Johnston *et al*., 1986; Maeir *et al*., 1989; Payton *et al.*, 1989; Jenkins & Ali, 2000; Ali *et al*., 2004) but relatively little has been published on the mechanisms by which P supply influences growth processes and yield formation. Jenkins and Ali (1999) demonstrated that the beneficial effect of phosphate fertilizer on growth could be explained in terms of enhanced early canopy growth and increased radiation interception.

Relatively large amounts of fertilizer P are frequently applied to potato crops and economic responses occur where residual levels of P are low. Inefficient utilization of fertilizer P leads to accumulation of P in soils especially where potatoes are grown frequently in the rotation. Increasing concern over phosphate pollution indicates the need to re-evaluate the P needs of potato crops. Earlier studies relating to phosphorus requirements of potatoes have shown that soil P tests are useful to identify soils deficient in phosphorus and provide a guide as to the magnitude of the crop's response to applied phosphorus (Tyler *et al*., 1961). From the relationships between rate of applied P and yield response obtained in such studies, an indication may also be obtained about the rates of phosphorus growers should apply.

Phosphorus application increases the rate of canopy expansion but advances senescence. However, relative ground cover is the proportion of ground covered by green foliage, expressed as percentage. It is a most important variable for crop growth models based on intercepted solar radiation because of its close relationship with the fraction of radiation intercepted (Ali, 1998). The objectives of present research work were to examine the mechanism by which the field grown crops respond to phosphorus application and to analyse the relative response of potato cultivar Desiree in terms of leaf area index, dry matter production and phosphorus uptake under conditions of low residual soil P.

MATERIALS AND METHODS

The present study was conducted at Morfa Mawr Field Research Station, Welsh Institute of Rural Studies, University of Wales, Aberystwyth, UK during 1995 to study the effects of phosphorus fertilizer on growth and development of potato cv. Desiree on a deep sandy loam soil. In this experiment, six phosphorus fertilizer levels were compared, viz. 0, 50, 100, 200, 300 and 400 kg P_2O_5 ha^{-1}. The management of seed tubers prior to planting was made in such a way that tubers of uniform sized (30-35 g) were trayed up in wooden trays and placed at 4 ^{0}C in a controlled-temperature cabinet. All the seed tubers were sprayed in the trays with Rizolex (active ingredient tolclofos methyl) to prevent stem canker caused by *Rhizoctonia solani*. Then seed tubers were transferred to a cabinet operating at 9 ^{0}C until planting. Sprout measurements were made which indicated that sprout length was less than 3 mm by planting.

Land was thoroughly cultivated prior to planting and ridged at a row spacing of 70 cm. All the fertilizers were applied by hand (by broadcast method) between the ridges in each plot (i.e. all N, K and various rates of P). Nitrogen and potassium fertilizers were applied at the rate of 150 kg N ha^{-1} and 250 kg K_2O ha^{-1} in the form of ammonium nitrate (Nitram, 34.5% N) and Muriate of Potash (60% K_2O), respectively. P fertilizer was applied to each plot separately, as determined by the treatments, in the form of Triple Superphosphate (46% P_2O_5). Ridges were then split back to recreate the new ridges over the furrows where fertilizer had been placed thereby ensuring that after planting all the nutrients applied were just below the seed tubers.

The experiment was laid out in a randomized complete block design with four replications using a net plot size of 18.82 m^2. Seed tubers were planted using hand-held planters, which placed the tubers into the ridge at a depth of 12 - 15 cm. After planting, the ridges were returned to their original shapes by hand raking. Each plot comprised four rows each with 24 plants. Spacing was 28 cm between plants within rows and 70 cm between rows, which gave a planting density of 5.1 plants m^{-2}. Pre-emergence herbicide was applied immediately after planting. After 40 days of planting, plants were harvested with an interval of 2 weeks for data collection.

Samples were taken from the field by hand digging each plot on 14 June, 28 June, 12 July, 26 July, 09 August, 23 August, 06 September, 20 September and 04 October. In all cases, the harvested plants were surrounded by guard plants. The samples were analysed as plant parts were separated, total sample leaf area and leaf area index were derived from the total leaf dry weight and the area per unit of dry weight of the leaf sub-sample. The dried samples from each harvest were milled and analysed for nitrogen, phosphorus and potassium contents. The P concentration in dried samples was determined by colorimetry using an autoanalyser as described by Faithfull (1971).

RESULTS AND DISCUSSION

Results indicate that there were significant differences in leaf area index (L) between different phosphorus levels at early harvest dates resulting from increased L following application of phosphate fertilizer (Table I). On 28 June, leaf area index (L) increased with each increment in added phosphate and each of the lower rates (0, 50 and 100 kg/ha) gave significantly lower L values than 400 kg ha^{-1}. Ground cover (% age) recorded on 30 June gave mean values of 45.0, 47.2, 52.0, 55.3, 56.9 and 56.8 for 0, 50, 100, 200, 300 and 400 kg P_2O_5 ha^{-1} levels, respectively. Till 18 July, ground cover values increased consistently with each increment in added phosphate.

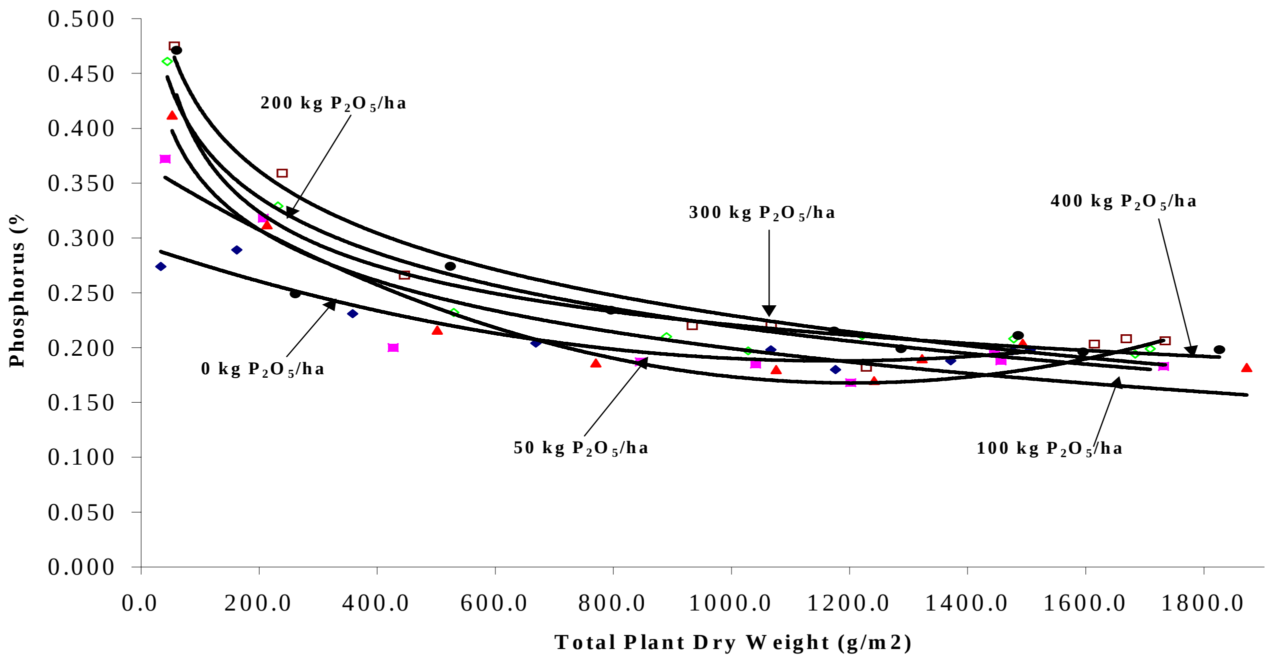
L increased to reach a peak on 23 August in the lower rates and the higher rates (i.e. 200, 300 and 400 kg P_2O_5 ha^{-1}) gave peak L earlier i.e. at 200 and 300 kg P_2O_5 ha^{-1}, the peak L was achieved on 26 July and at 400 kg P_2O_5 ha^{-1} on 9 August. Similar results were recorded in the case of ground cover. Positive responses to P application for L were only observed at early stages of growth. It may be assumed, that the P application increased radiation interception during

Table I. Leaf area index (L) as affected by different phosphorus levels at different sampling dates

P levels	Harvest dates							
(Kg P_2O_5 ha^{-1})	14 Jun.	28 Jun.	12 Jul.	26 Jul.	09 Aug.	23 Aug.	06 Sep.	20 Sep.
0	0.43	1.63	2.96	4.00	4.97	5.34	4.17	2.48
50	0.57	2.22	3.31	4.67	4.73	4.86	3.97	3.16
100	0.77	2.24	3.58	4.22	4.55	4.71	4.30	2.62
200	0.67	2.43	4.11	5.03	4.24	4.86	3.76	1.59
300	0.83	2.61	3.50	5.18	4.81	4.90	3.79	4.04
400	0.85	2.67	4.20	4.44	5.06	4.71	3.93	1.99
SE	0.073	0.144	0.244	0.464	0.286	0.377	0.317	0.519
LSD (5%)	0.22	0.43	0.74	-	-	-	-	-
P	<0.01	<0.01	<0.05	ns*	ns	ns	ns	ns

*Non-significant

Fig. 1. Effect of different phosphorus fertilizer rates on the relationship between total plant dry weight (g/m^2 and phosphorus percentage in plants



the early stages of growth. In the present study, at the higher phosphate level, senescence occurred earlier as it was found at the final harvest, on 20 September, that the lowest L (1.59 and 1.99) were recorded for the 200 and 400 kg ha^{-1} phosphate levels, respectively. Similar results were found by Fernando (1958), as he reported that N and P, while accelerating leaf production, also hastened senescence. The greater early L where 100, 200, 300 or 400 kg P_2O_5 ha^{-1} were applied resulted in more dry matter production at early stages of growth as a consequence of greater radiation interception early on.

The phosphorus application increased the total plant dry matter at the early three harvests (Fig. 1). The higher phosphorus rates (i.e. rates > 50 kg P_2O_5 ha^{-1}) did not generally differ significantly from each other. There were effects in total plant dry weight early on but not later. This would be consistent with more radiation intercepted early on in growth. There was some evidence from ground cover scores that leaf senescence occurred earlier at higher P rates although effects on L at later stages of growth were not conclusive. Other studies have also noted the link between high P availability and earlier senescence (Watson, 1963).

Fertility is one of the major controllable factors that affect the yield and quality of potatoes. Phosphorus is considered a very important element, which makes its contribution through effects on cell division, fat and albumin formation, flowering and fruiting including seed formation, root development and crop maturation. Phosphate (orthophosphate) with CO_2 and H_2O is considered to be a primary substrate of photosynthesis (Walker & Sivak, 1986). Hence the importance of phosphorus for plant growth metabolism is apparent. In the present study, P application increased total P uptake with increase in P content of plants in most cases. Differences, however, were not significant at all harvests (Fig. 1). On 4 October, treatments 200 and 300 kg P_2O_5 ha^{-1} showed a decrease in P uptake. With the exception of these two treatments, all other treatments showed maximum P uptake at final harvest.

In general, positive responses to P application were observed at all early stages of growth (i.e. leaf area index and total plant dry weight). Responses in the second half of the growth period were, however, relatively small and in most cases non-significant. One can conclude therefore, that the residual levels of available P in the soil were sufficient at least as far as mature yield was concerned. The responses at early harvests, however, suggest that early harvested crops may show a worthwhile benefit and yield response to P application even under such conditions of residual soil P.

REFERENCES

Ali, H., 1998. Studies on phosphorus nutrition of potatoes. *Ph.D. Thesis*, University of Wales, Aberystwyth, UK.

Ali, H., M.A. Anjum and S.A. Randhawa, 2004. Influence of phosphorus on yield potential of potato (*Solanum tuberosum* L.) crops. *Int. J. Agric. Biol*., 6: 165-67.

Faithfull, N.T., 1971. Automated simultaneous determination of nitrogen, phosphorus, potassium and calcium on the same herbage digest solution. *Lab. Pract.*, 20: 41-44.

Fernando, L.H., 1958. Studies on leaf growth: Effect of mineral nutrients and interdependence of the leaves of a plant. *Ph.D. Thesis,* University of London, UK.

Gupta, A. and M.C. Saxena, 1976. Evaluation of leaf analysis as a guide to nitrogen and phosphorus fertilization of potato (*Solanum tuberosum* L.). *Plant & Soil*, 44: 597-605.

Jenkins, P.D. and H. Ali, 1999. Growth of potato cultivars in response to application of phosphate fertilizer. *Ann. Appl. Biol*., 135: 431-38.

Jenkins, P.D. and H. Ali, 2000. Phosphorus supply and progeny tuber numbers in potato crops. *Ann. Appl. Biol*., 136: 41-46.

Johnston, A.E., P.W. Lane, G.E.G. Mattingly, P.R. Poulton and M.V. Hewitt, 1986. Effects of soil and fertilizer P on yields of potatoes, sugar beet, barley and winter wheat on a sandy clay loam soil at Saxmundham, Suffolk. *J. Agric. Sci. (Cambridge)*, 106: 155-67.

Maier, N.A., K.A. Potocky-Pacay, J.M. Jacka and C.M.J. Williams, 1989. Effect of phosphorus fertilizer on the yield of potato tubers (*Solanum tuberosum* L.) and the prediction of tuber yield response by soil analysis. *Australian J. Exp. Agric*., 29: 419-32.

Payton, F.V., R.D. Rhue and D.R. Hensel, 1989. Mitscherlich-Bray equation used to correlate soil phosphorus and potato yields. *Agron. J.*, 81: 571-76.

Soltanpour, P.N. and C.V. Cole, 1978. Ionic balance and growth of potatoes as affected by N plus P fertilization. *American Potato J*., 55: 549-60.

Tucker, M.R., 1999. Essential plant nutrients: their presence in North Carolina soils and role in plant nutrition. NCDA and CS Miscellaneous Publication. North Carolina Department of Agriculture and Consumer Services, pp. 1-12.

Tyler, K.B., O.A. Lorenz and F.S. Fullmer, 1961. Plant and soil analyses as guides in potato nutrition. *California Agric. Exp. Sta., Bull.* No. 781.

Walker, D.A. and M.N. Sivak, 1986. Photosynthesis and phosphate: a cellular affair. *Trends Biol. Sci*., 11: 176-79.

Watson, D.J., 1963. Some features of crop nutrition. *In:* J.D. Ivins and F.L. Milthope (Eds.). *Growth of Potatoes,* pp: 233-46. Butterworths Scientific Publications, UK

Westermann, D.T. and G.E. Kleinkopf, 1985. Phosphorus relations in potato plants. *Agron. J*., 77: 490-94.

(Received 10 January 2004; Accepted 16 February 2004)