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Influence of Phosphorus on Yield Potential of Potato (*Solanum tuberosum* L.) Crops

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ABSTRACT

The effect of soil applied phosphorus on tuber numbers and yield of potatoes was studied. In this experiment, sprouted seed tubers of cultivar Desiree were used with six different levels of phosphorus fertilizer (i.e. 0, 50, 100, 200, 300 and 400 kg P_2O_5 ha^{-1}. Results indicated that there were highly significant differences in the number of tubers at some harvest dates. However, the 400 kg P_2O_5 ha^{-1} treatment gave highest number of tubers m^{-2} at harvest dates on 14 and 28 June, 12 July, 20 September and 04 October and the zero P treatment gave the lowest number of tubers at all harvest dates. Tuber fresh weight as affected by different rates (0-400 kg P_2O_5 ha^{-1}) of phosphorus fertilizer gave significant differences between treatments at harvest on 12 July ($P < 0.05$), although at earlier harvests uptill 23 August, the zero level tended to give consistently lower yields.

Key Words: Phosphorus; Tuber numbers; yield

INTRODUCTION

Early growth of potato plants is characterized by limited root concentration and poor capacity to exploit soil nutrient reserves. Movement of available phosphate in soil occurs by diffusion primarily, and is therefore a slow process. It is suggested that the zones of depletion of phosphate are restricted to regions surrounding active roots (Tisdale & Nelson, 1975; Gregory, 1988). 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). On soils containing sub-optimum levels of available P, potato crops show economic responses to the application of phosphate fertilizer (Jenkins & Ali, 1999) and, as a result, relatively large amounts are applied in commercial practice.

The potato crop has traditionally been regarded as having a large requirement for phosphorus (P) with the results that substantial applications of phosphate fertilizer are frequently made in anticipation of significant economic yield responses. Numerous studies have been found the relationships between P availability and yield (Johnston *et al*., 1986; Maeir *et al*., 1989; Payton, Rhue & Hensel, 1989; Jenkinss & Ali, 2000) 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. The work presented here examines in field grown crops the effects of P supply on progeny tuber numbers, a relationship widely recognized but rarely documented in the literature, and considers the consequences for tuber size grading.

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. Tyler *et al.* (1961) 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. From the relationships between rate of applied P and yield response obtained in such studies, an indication may also be obtained as to the rates of phosphorus growers should apply.

The optimum number of tubers is an important objective in potato production as this is one of the variables determining mean tuber size and tuber size distribution. A number of factors influence the tuber number and most of these are reasonably well documented in the literature, e.g. stem number (Allen & Wurr, 1992), moisture supply (MacKerron & Jefferies, 1986), radiation environment (O'Brien *et al.*, 1998), disease (Hide *et al.*, 1985). Temperature has also been shown to influence tuber number but the relationships are often complex (Struik *et al.*, 1989). The Objective of this study was to establish whether, in addition to those factors mentioned above, soil applied phosphorus should also be considered a significant determinant of the number of tubers produced by potato crops.

MATERIALS AND METHODS

The experiment conducted at Morfa Mawr Field Research Station, University of Wales, Aberystwyth, UK examined the effects of soil applied P on tuber numbers and yield in potato crops of cv. Desiree on a deep sandy loam soil. In experiment, six fertilizer P 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 size ranges (30-35 g) were trayed up in wooden trays and placed in a 4^0C controlled temperature cabinet. All the seed was sprayed in the trays with Rizolex (active ingredient tolclofos methyl) to prevent stem canker caused by *Rhizoctonia solani*. Then seed was transferred to a cabinet operating at 9^0C until planting. Sprout measurements were made which indicated that sprout length was less than 3 mm by planting.

All the fertilizers were applied by hand (broadcast) 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 Nitram (34.5% N) and Muriate of Potash (60% K_2O) respectively. P fertilizer was applied by hand between the ridges to each plot separately, as determined by the treatments, in the form of triple super phosphate (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. 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 after planting.

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. The samples taken on 14 June, 28 June, 12 July, 26 July and 04 October consisted of two plants per plot while those on 09 August, 23 August, 06 September and 20 September consisted of four plants. In all cases, the harvested plants were surrounded by guard plants.

The samples were analysed as plant parts were separated, tubers were graded into different size ranges and the numbers and weight in each grade recorded. 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

Total tuber numbers per unit area as influenced by different levels of phosphorus fertilizer are presented in Table I, which indicates that there were highly significant differences in the number of tubers at some harvest dates. In the experiment reported here, the 400 kg P_2O_5 ha^{-1} treatment gave the highest numbers m^{-2} on 14 June, 28 June, 12 July, 20 September and 04 October and zero P_2O_5 treatment gave the lowest number of tubers m^{-2} at all harvest dates. The largest treatment differences were found on 28 June. At this time, tuber number increased with increase in P level,

Table I. Total tuber numbers m^{-2} as affected by different phosphorus (P_2O_5) levels at different sampling dates

P Levels	Harvest Dates								
(kg ha^{-1})	14 Jun.	28 Jun.	12 Jul.	26 Jul.	09 Aug.	23 Aug..	06 Sep.	20 Sep.	04 Oct.
0	22.3	58.7	63.1	59.9	55.5	56.1	53.9	59.0	58.0
50	29.3	65.0	69.5	63.8	70.1	65.7	55.1	59.0	63.1
100	31.9	72.0	93.1	65.7	71.7	79.4	58.7	71.4	65.0
200	21.9	95.6	86.7	89.3	76.2	88.0	76.5	76.8	70.8
300	36.3	81.6	79.1	82.2	75.9	89.9	79.7	78.1	71.4
400	40.2	110.3	94.4	77.1	75.5	81.0	74.9	82.6	72.0
SE	10.54	6.83	10.90	7.37	2.99	7.07	5.42	5.07	8.73
LSD (5%)	-	20.6	-	-	9.0	21.3	16.3	15.27	
P	ns	<0.001	ns	ns	<0.01	<0.05	<0.01	<0.05	ns

Table II. Total tuber fresh weight (t ha^{-1}) as affected by different P levels (P_2O_5) at nine harvests

P Levels	Harvest Dates								
(kg ha^{-1})	14 Jun.	28 Jun.	12 Jul.	26 Jul.	09 Aug.	23 Aug..	06 Sep.	20 Sep.	04 Oct.
0	0.1	5.1	13.9	22.2	33.9	43.2	55.0	59.4	63.6
50	0.1	6.2	16.3	28.5	38.4	45.2	56.4	58.6	73.5
100	0.3	6.4	19.7	26.0	37.6	46.2	50.4	59.1	81.5
200	0.1	6.6	21.2	29.2	36.4	46.6	59.8	69.1	76.4
300	0.3	6.8	17.2	31.3	36.5	46.2	59.9	69.2	71.3
400	0.3	7.8	19.5	25.3	40.5	47.4	56.6	62.9	80.3
SE	0.09	0.81	1.46	2.65	1.79	2.37	3.11	3.28	5.61
LSD (5%)	-	-	4.41	-	-	-	-	-	-
P	ns	ns	<0.05	ns	ns	ns	ns	ns	ns

although, 200 and 400 kg P_2O_5 ha^{-1} did not differ significantly from each other. Overall, phosphorus application gave responses to increase tuber number m^{-2} upto about 200 kg P_2O_5 ha^{-1}.

The yield of potatoes is a function of the number of tubers produced and the average weight per tuber. Phosphorus contributes to early development of the crop, early tuberization and increases the number of tubers per plant (Jenkins & Ali, 2000). Ali (1998) also concluded that phosphorus increases the number of tubers per plant. Dubetz and Bole (1975) reported that number and tuber yield increased upto 224 kg P_2O_5/ha, and further added that mean weight per tuber continued to increase upto the highest P rate (448 kg P_2O_5/ha) but the number of tubers did not increase.

Data on tuber fresh weight as affected by different rates (0-400 kg $P_2O_5ha^{-1}$) of phosphate fertilizer are presented in Table II There were significant differences between treatments at harvest on 12 July ($P < 0.05$) but at all other harvest dates no significant results were observed between different phosphate rates, although at earlier harvests uptil 23 August, the zero level tended to give consistently lower yields.

On 12 July, the highest tuber fresh weight of 21.2 t ha^{-1} was produced in the 200 kg P_2O_5 ha^{-1} treatment which, however, was only significantly greater ($P < 0.05$) than the treatments 0 and 50 kg ha^{-1} which gave values of 13.9 and 16.3 t ha^{-1}, respectively. Further, it is evident from the data that tuber fresh weight increased with time over the whole harvesting period. In general, positive responses to P application were observed at all early stages of growth (i.e. total plant dry weight, tuber number and tuber yield etc.). 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.

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