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Effect of Nitrogen, Phosphorus and Potassium Fertilization on the *Koenigia islandica* Growth in the Field

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ABSTRACT

Koenigia islandica has a disjunctive Arctic and sub Arctic circumpolar distribution extended Southward to several isolated mountain ranges of Northern Europe, Asia and North America. The population of this plant on the Isle of Skye at altitude 461-726 m and on Isle of Mull at 385-523 m is the most Southerly in Europe and, therefore, the most vulnerable to the climatic fluctuations on numbers and survivorship. Annual habit of *K. islandica* makes it particularly vulnerable to adverse conditions. Increased microbial activity due to elevated temperature in tundra soil provides nutrients, particularly nitrogen, to plants. Therefore, *K. islandica* will be outcompeted by other plant species. Conservation biologists need to monitor theses changes when species cannot adapt to climate change.

Key Words: Population; *Koenigia islandica;* Competition; Isles of Mull; Isles of Skye

INTRODUCTION

Koenigia islandica has a disjunctive Arctic-sub Arctic circumpolar distribution extended southward to several isolated mountain ranges of Europe. It is, therefore the most vulnerable to the impact of climatic fluctuations on numbers and survivorship (Crawford *et al.*, 1993). It is typically associated with bare very mobile substrate that are very unstable for perennial plants to establish and outcompete this very small plant (Rashid *et al.*, 2003), *K. islandica* has also been reported to have a small seed bank, with approximately 90% of the viable seeds in the soil germinating each year (Reynold, 1984a). The average number of seeds produced per plant is usually less than 10 (pers. obs.). Due to increased concentrations of carbon dioxide in the atmosphere it is predicted from Global Circulation Models that winter temperature will rise more than summer (Houghteon *et al.*, 1990). However, the consensus among the meteorologist is that the world climate will increase in temperature by an additional 1°C to 3.5°C over the next century as result of increased level of carbon dioxide and other gases (Primack, 1998). This implies that frequency of freeze thaw cycles will be reduced much and consequently soils in the uplands will become more stable and warm.

The very low rates of decomposition of organic matter result in very low rates of turnover of macronutrients, particularly nitrogen and phosphorus, in tundra soils (Widden, 1977; Crawford, 1989). Recent studies have also shown that nutrients are often the most important factor in limiting plant productivity in tundra ecosystems. This is primarily due to the fact that soils are very slow to warm-up below the top few centimetres. Consequently, the microbial activity and, therefore, mineralization of organic matter is very slow. The climate warming will increase the microbial activity hence nutrient availability to plants. Due to reduced frequency of freeze thaw cycles and increased microbial activity, the *K. islandica* will be outcompeted. The aim of the project was to examine NPK fertilization effect on plant productivity of *K. islandica* in tundra ecosystems in the field.

MATERIALS AND METHODS

In order to establish whether nutrients were limiting the size of *K. islandica* plants growing in the field it was decided to carry out a factorial fertilizer application experiment at one site on Beinn na h'Iolaire (NM 452313) on Mull. Nitrogen, phosphorus and potassium were supplied singly and in each possible combination to an area of 6 × 6 m on a relatively flat terrace where *K. islandica* is reasonably abundant and the terrain is as uniform as possible within the confines of such an area. Using factorial design it, therefore, would be possible to establish which element was the most limiting to above ground biomass production of the *K. islandica* plants.

Levels of different nutrients were chosen on the basis of recent fertilizer experiments carried out on tundra vegetation (Shaver, & Chapin, 1980, Chapin, pers. comm.). The fertilizers were supplied as a single dose in solution using a watering can with a fine nozzle in order that the nutrients were applied evenly over each of the 1 m^2 plots which were marked with a line of small stones. Marker posts could not be used due to past experience showing that sheep and deer would remove marker pegs from the loose substratum. The nutrient solutions were dispersed in approximately 2 L of lochan water. Nitrogen was supplied at a rate of 5 g m^{-2} as NH_4NO_3, whilst potassium and phosphorus were supplied at a rate of 4 g m^{-2} as KCl and

H_3PO_4, respectively. The nutrients were added on 30th April 1998.

There were four replicate plots for each of the eight possible treatments, including the control, and they were randomized within the 6 m x 6 m plot (Fig. 1). The control plots received lochan water without any additional nutrients

To avoid edge effects, plants from the central 0.5 m x 0.5 m of the treated plots were harvested, which gave a 0.25 m wide unsampled border for each sub-plot. All plants from the central 0.5 x 0.5 m area were harvested on 29th of August 1998. The plants were carefully dried on return to Bradford within 2 days of harvesting. A composite soil sample from each replicate treatment was taken by combining 5 samples of the top 5 cm of substratum. The soil samples were analyzed for particle size distribution as well as plant-available ammonium, nitrate, potassium and phosphate. The same treatments were applied to the same plots in May 1999 and harvested in August 1999.

Another set of plots were established towards the summit of Beinn na h'Iolaire where there was a large number of *K. islandica* plants in the summer of 1997. A total of sixteen 0.5 x 0.5 m plots were marked with stones in August 1997 and nitrogen, phosphorus and potassium added as single nutrient additions. The same solutions and the concentrations were used as for the factorial combination described above using the same lochan water. Plants were harvested on 28th August 1998 and dried and weighed as described above.

RESULTS

Concentration of available nitrogen in the soils from control plots were extremely low while higher values in fertilized plots indicated that the applied fertilizer had became available for plant growth. A comparison of the biomass of *K. islandica* plants indicated a positive response in growth to the applied fertilizer. Application of nitrogen alone resulted in a large increase in average dry weight of *K. islandica* plants compared to control plots (Fig. 2). Phosphorus applied alone did not show any significant increase in average plant weight compared to the control. A combination of nitrogen and phosphorus applied also resulted in an increase of mean plant weight, which was significantly different from control, but not from nitrogen treatments alone or with potassium. These results demonstrate that the availability of nitrogen, rather than phosphorus, is a major factor limiting the growth of *K. islandica* at this particular site (Fig. 2). Concentrations of available potassium are relatively high at this particular and therefore this element is not likely to limit production of plants on these or most basalts.

Fig. 1. Layout plan for factorial fertilization experiment carried out on a gravel terrace on the mean aboveground dry weights of Iceland purslane (*K. islandica*) plants. Nitrogen (N), phosphorus (P) and potassium (K) all applied at a rate of 5 g m^{-2} as NH_4NO_3, 4 g m^{-2} as H_3PO_4 or KCl, respectively

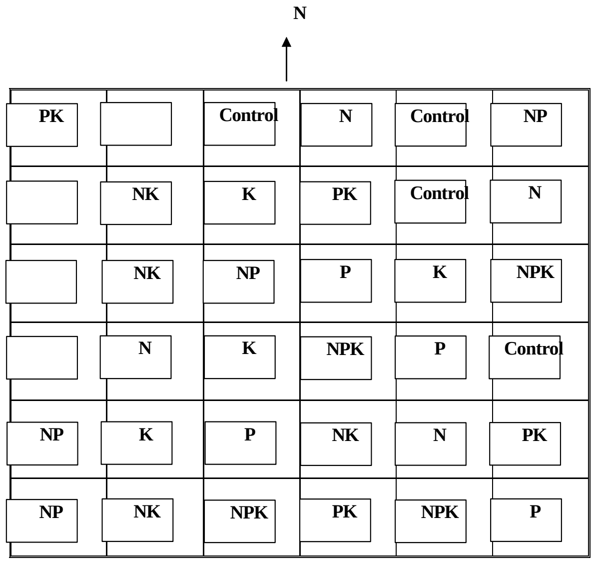
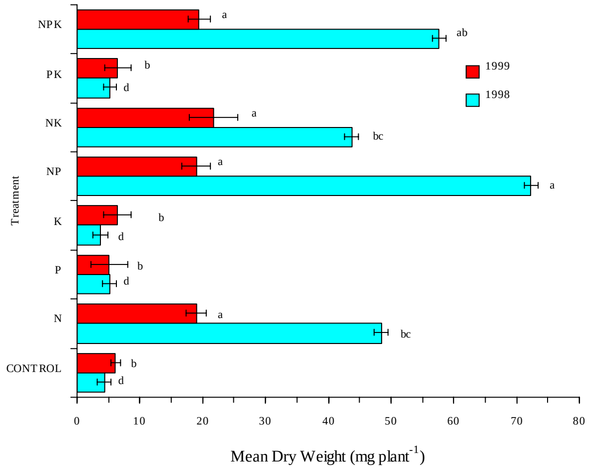
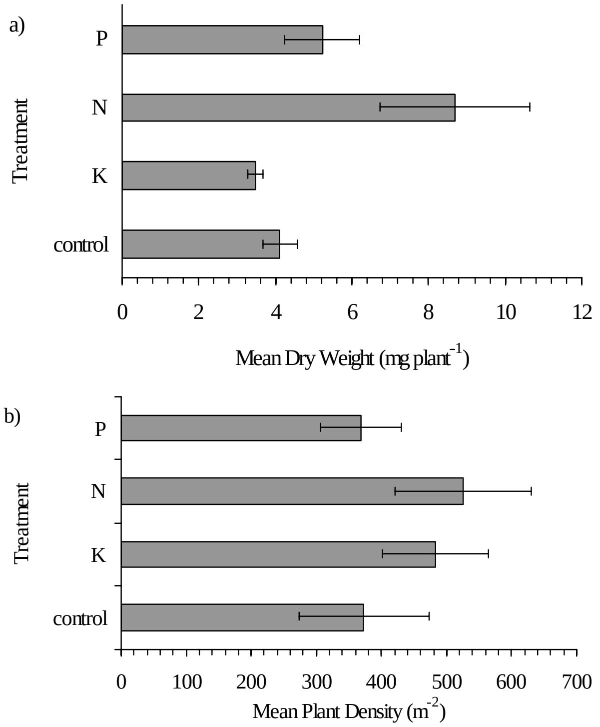


Fig. 2. The effects of a factorial fertilization experiment carried out on a gravel terrace on the average aboveground dry weights of Iceland purslane (*K. islandica*) plants. Nitrogen (N), phosphorus (P) and potassium (K) all applied at a rate of 5g m^{-2} as NH_4NO_3,4g m^{-2} H_3PO_4 or KCl. Control plots received lochen water. Means are shown with one standard error of the mean. Significant differences between means for the same year are shown by different letters



There was no significant fertilizer effect on the numbers of plants per plot (Fvar = 0.837, P = 0.57). The average dry weight per *K. islandica* plant on the summit also increased significantly with the application of nitrogen fertilizer (Fvar = 14.69, P = 0.0003), but the effect was not great. As with the other experiment, the density of plants was not significantly altered by any of the fertilizer applications to the plots on the summit of the hill (Fig. 3).

Fig. 3. The effects of fertilization with either ammonium-nitrate (N) or NaH_2PO_4 (P) or KCl (K) on a) the average dry weight (mg plant^{-1}) and b) density of plants of *K. islandica* on bare weathered regolith on the summit of Beinn na h'Iolaire, Mull in 1998. Means of four replicate plots with one standard error of the mean represented by the whiskers



The fertilizer experiment was repeated in 1999 on exactly the same plots (Fig. 2), and gave very similar results to the previous year. However, this time the average weight of *K. islandica* plants fertilized with nitrogen alone or with other element was lower than in the previous year. This was almost certainly due to the much greater growth of other competing plants, particularly the moss *Oligotrichum hercynicum.* This species responded the most to the addition of nitrogen and phosphorus together. Bigger and Oechel (1982) observed that mosses take up nutrients rapidly and can compete with vascular plants in tundra sites.

Soil analysis after the completion of the experiment on the summit in 1998 showed no increase in the nutrients compared with control (Figs. 4 & 5). This indicated that most of the applied nutrients had been out of thin soil by high rainfall that this site receives. Particle size analysis of the soil (Fig. 6) showed that there was no significant (P>0.05) difference in the inherent proportion of gravel between the plots, and therefore the fertilizer effects are unlikely to be due to variation in other environmental variables across the site (Fig. 2).

Fig. 4. The mean concentration (mg kg^{-1}) of nitrate-(yellow) and ammonium-nitrogen (red) and soluble reactive phosphate (green) in August 1998 in plots treated with a single application of either ammonium nitrate, $Na_2H_2PO_4$ or KCl at a range of rate of 5 g m^{-2} in August 1997. Means of at least 4 replicate

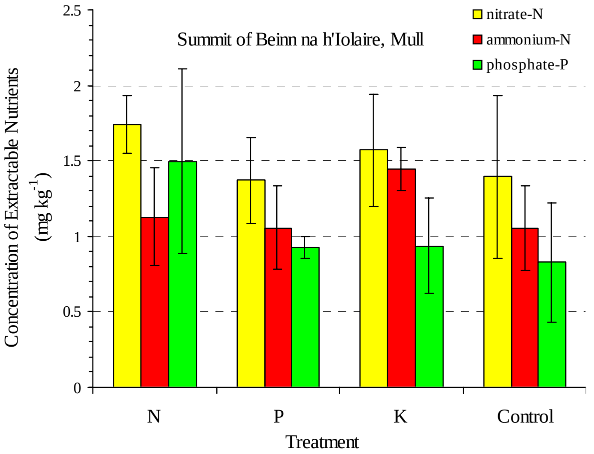
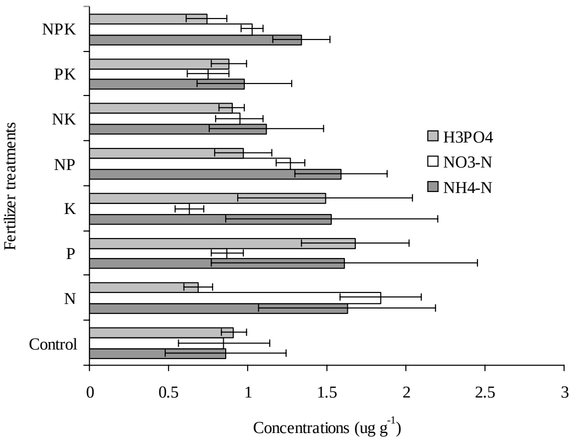


Fig. 5. The mean concentration (μg g^{-1}) of nitrate, ammonium-nitrogen and soluble reactive phosphate in September 1998 in plots treated with all possible combinations of NPK at a rate of 5gm^{-2} in 29th April 1998. Average of 4 replicate



DISCUSSION

Growth of *K. islandica* is limited primarily by a low rate of supply of nitrogen as shown by the marked increase in size of plants in the nitrogen fertilized plots on Mull (Fig. 2). Douglas and Tedrow (1959) found decomposition rates strongly dependent on soil temperatures and calculated organic matter decomposition to be 2.8% per annum. The availability of phosphorus is also limited by low rates of decomposition, but this has little direct effect on bio-mass production (Haag, 1974). Chapin (1980) suggested that rapidly growing species from high nutrient habitats show

Fig. 6. the particle size distribution of the regolith in different fertilized plots on Beinn na h' Iolaire, Mull. Means of 4 replicate with bars representing one standard error of the mean

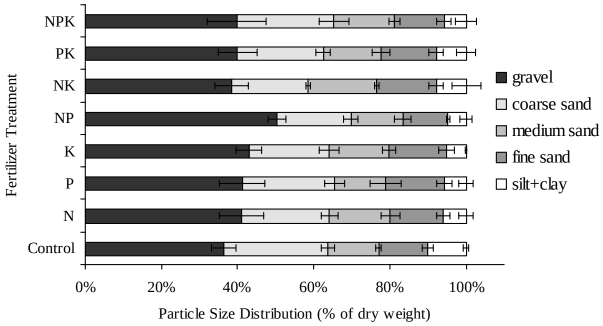
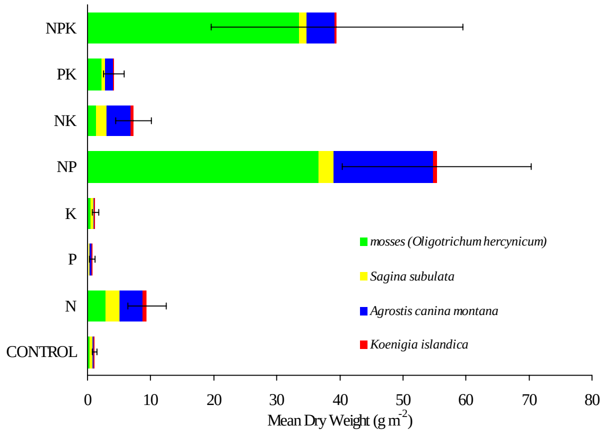


Fig. 7 The mean dry weight of different species in the second year of a factorial fertilization experiment on an unvegetated terrace of weathered basalt on Beinn na h'Iolaire, Mull. Means of 4 replicate plots with bars representing one standard error of the mean total weight per plot



considerable phenotypic plasticity in root/shoot ratio and generally have a higher ratio at low availability and a lower ratio at high availability than do species from low-nutrient habitat.

However, the repetition of the experiment on the terrace showed that *K. islandica* could not compete with other vascular plants or even mosses which responded more to increased nutrient supply (Bigger & Oechel, 1982) compared to *K. islandica* (Fig. 7).

CONCLUSION

The size of *K. islandica* plant is limited primarily by the availability of nitrogen in wet sites. However, the availability of nutrients can also limit the size of *K. islandica* plants in better-drained sites as nutrient are readily leached from soils with low cation exchange capacity in areas of high rainfall, as observed by the analysis of the soils in the fertilized plots at the completion of the experiments. *K. islandica* is typical of arctic-alpine due to being tolerant of low nutrient supply, particularly nitrogen. However, the strong positive response to fertilizations provided the drought is not a problem, indicates a moderate degree of phenotypic plasticity with respect to aboveground biomass production. However continued fertilization would undoubtedly allow other species to ultimately out compete *K. islandica* in more fertile locations.

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REFERENCES

Bigger, C.M. and W.C. Ochel, 1982. Nutrient effect on maximum photosynthesis in arctic plants. *Holarctic Ecol*., 5: 158–63

Crawford, R.M.M., 1989. Studies in plant survival. *In: Ecological Case Histories of Plant Adaptation to Adversity*. Blackwell, Oxford.

Crawford, R.M.M., H.M. Chapman, R.J. Abbot and J. Balfour, 1993. Potential impact of climatic warming on Arctic vegetation. *Flora* 188: 308–12

Chapin, F.S., 1980. The mineral nutrition of wild plants. *Ann. Rev. of Ecol. and System*, 11: 233–60

Douglas, T.A. and J.C.F. Tedrow, 1959. Organic matter decomposition rates in arctic soils. *Soil Sci.,* 88: 305–12

Haag, R.W., 1974. Nutrient limitations to plant production in two tundra communities. *Canadian J. Bot.,* 52: 103–16

Houghton, J.T., and G.J. Jenkins, 1990. Climate Change. In: *The IPCC Scientific Assessment*. University of Cambridge, Cambridge

Primack, R.B., 1998. *Essentials of Conservation Biology,* (2nd ed.), pp. 242. Boston University, USA

Rashid, Q., A.D. Headley and D.P.M. Comber, 2003. The distribution and ecology of the arctic plant Iceland purslane (*Koenigia islandica*) in Scotland. *Pakistan J. Biol. Sci*., 6: 252–4

Reynold, D.N., 1984. Alpine annual plants: phenology, germination, photosynthesis and growth of three rocky mountain species. *Ecol*., 65: 759–66

Reynolds, D.N., 1984. Population dynamics of three annual species of Alpine plants in the Rocky mountains. *Oecol.,* 62: 250–5

Shaver, G.R. and F.S. Chapin III, 1980. Response to fertilization by various plant growth forms in an Alaskan tundra: Nutrient accumulation and growth. *Ecol.,* 61: 662–75

Widden, P., 1977. Microbiology and decomposition on Truelove Lowland. *In:* Bliss, L.C. (ed.) *Truelove Lowland, Devon Island, Canada: a high Arctic ecosystem*, pp. 505–30. University of Alberta Press, Edmonton

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