# ADAPTIVE RESPONSES OF AN ALKALINE SOIL POPULATION OF *CYNODON DACTYLON* (L.) PERS. TO NPK NUTRITION

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## INTRODUCTION

Little information is available regarding differentiation of ecotypes within native species with respect to requirements for nitrogen, phosphorus and potassium. Ramakrishnan (1971) has recently reviewed the literature on phosphorus and calcium nutrition related to the calcicole-calcifuge phenomenon. Some information is also available on the differences in micro-nutrient requirements of natural populations related to the calcicole-calcifuge situation (Ramakrishnan 1968, 1969, 1971) and also on the heavy-metal-tolerant populations of normally susceptible species (Bradshaw *et al.* 1965; Turner 1969). Differences between populations of *Trifolium repens* L. in response to potassium have been reported by Snaydon & Bradshaw (1969). Recently a differential response to nitrogen, phosphorus and potassium has been shown for ecotypes of *Cynodon dactylon* (L.) Pers. from soils of varied calcium carbonate status and this was related to the conditions prevailing in the habitats of the populations sampled (Ramakrishnan & Gupta 1972).

Because the pH of alkaline soils is higher than in usual soils and the concentrations of potassium and sodium are greater, the availability of nitrogen, phosphorus and potassium may be quite different. The present paper deals with the differential responses to varied levels of these three nutrients in two ecotypes of *C. dactylon* (L.) Pers., one from a normal soil collected from Chandigarh and one from an alkaline soil population collected from Nilokheri, about 100 km south-east of Chandigarh (both have $2n = 18$). The differences between these populations in their responses to excess salt have been reported earlier (Ramakrishnan & Nagpal 1973).

## MATERIALS AND METHODS

Sand-culture experiments were performed using clay pots of 12 cm diameter and small ramets of uniform size, with four leaves and of average fresh weight 0·06 g. The sand and pots were prepared following the procedure described in an earlier paper (Ramakrishnan & Nagpal 1973). One hundred millilitres of nutrient solution were added to each pot daily and this treatment was begun immediately after the introduction of the ramets. The sand was eluted with 500 ml of distilled water once a week. All experiments were replicated six times. Plants were allowed to grow for two months between October and December 1971 in a protected, unheated growth chamber, which provided shelter from wind and dust.

The plants were thus exposed to natural diurnal fluctuations in temperature, humidity and light.

The composition of the nutrient solution was basically the same as that given by Hewitt (1966) except for changes introduced in the levels of nitrogen, phosphorus and potassium: $Ca(NO_3)_2 . 4H_2O$, 1·3 mM; $NaNO_3$, 5 mM; $KNO_3$, 2 mM; $MgSO_4 . 7H_2O$, 1·5 mM; $NaH_2PO_4 . 2H_2O$, 1·3 mM. This solution had 133 ppm N, 40 ppm P and 78 ppm K.

In the first experiment nitrogen was provided at 63, 98, 133 and 213 ppm by varying the amounts of sodium nitrate in the nutrient solution without any compensatory changes in other salts. In the second experiment phosphorus levels were provided at 4·1, 41 and 124 ppm by varying the amount of $NaH_2PO_4 . 2H_2O$ without any compensatory changes in the other salts. In a third experiment, three levels of potassium, i.e. 7·8, 78 and 234 ppm were obtained by varying the amount of potassium nitrate. Compensatory changes in the amount of sodium nitrate were made to keep the nitrogen level constant. The pH of the nitrogen and potassium series of nutrient solutions was adjusted to 6·5. In the phosphorus series the pH was kept at 5 so as to avoid precipitation at high phosphorus levels. The pH of the nutrient solutions was adjusted using N sulphuric acid or N sodium hydroxide and an appropriate amount of sodium sulphate was used to compensate for the addition of sulphuric acid. The difference between the pH of the effluent and the intended value was found on all occasions to be not greater than 0·5.

At the conclusion of the experiments, the procedure outlined elsewhere (Ramakrishnan & Nagpal 1973) was followed for plant analysis.

Total nitrogen in the fresh soil samples was determined by the Kjeldahl method after sulphuric acid digestion in the presence of potassium sulphate and selenium. Inorganic nitrogen, which was very low in these soils compared to organic nitrogen, was reduced by finely powdered iron and dilute sulphuric acid before commencing the digestion (Piper 1944). Phosphorus was extracted in N sodium hydroxide and determined by the chlorostannous-reduced molybdophosphoric blue method. Exchangeable potassium was determined in an ammonium acetate extract after precipitation as potassium cobaltinitrite (Piper 1944). The values for soil analyses are the means of ten determinations made on soil taken from a depth of 0–5 cm.

## RESULTS

### *Soil*

The alkaline soil had much lower levels of total nitrogen and NaOH-soluble phosphorus but a much higher level of exchangeable potassium (Table 1).

### *Effects of varied nitrogen levels*

The whole-plant yield of the normal population improved as the applied nitrogen was increased, but that of the population from the alkaline soil decreased markedly at higher nitrogen levels (Fig. 1). The yield of the latter population was significantly higher than that of the normal population at 63 ppm nitrogen and the reverse was the case at 133 and 213 ppm levels. The shoot:root ratio of the normal population increased significantly as applied nitrogen was increased; that for the population from the alkaline soil was not significantly different at the various nitrogen levels. At higher nitrogen levels this ratio was significantly higher in the normal population than in the other. Nitrogen and phosphorus concentrations in the shoots of both populations generally increased with increased levels of nitrogen supplied to the roots (Fig. 1).

Table 1. *The pH and concentrations of nitrogen, phosphorus and potassium (mg per 100 g dry weight) at 0–5 cm in the two soils used in the experiments*

| | pH | Total nitrogen | Exchangeable potassium | NaOH-soluble phosphorus |
|---|---|---|---|---|
| Alkaline soil | 9·4 | 43 | 1117 | 9·7 |
| Normal soil | 7·2 | 1725 | 36·3 | 49·6 |

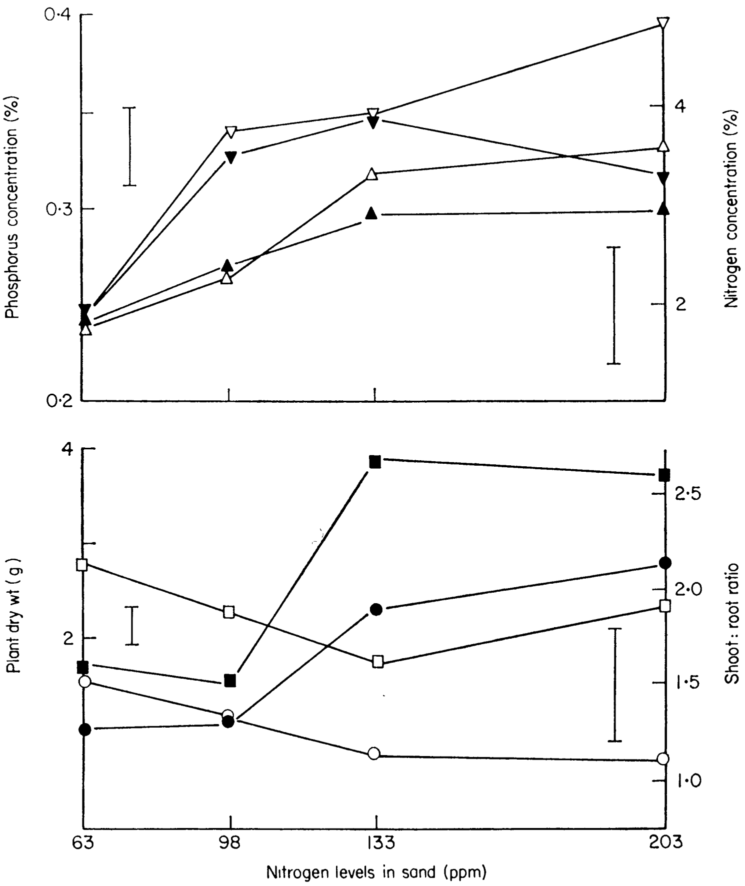


FIG. 1. The responses of the populations from a normal soil (filled symbols) and an alkaline soil (open symbols) to varied levels of nitrogen: ——●——, ——○——, plant dry weight; ——■——, ——□——, shoot:root ratio; ——▲——, ——△——, nitrogen concentration in the shoots; ——▼——, ——▽——, phosphorus concentration in the shoots. The vertical bars indicate least significant differences.

## *Effects of varied phosphorus levels*

The whole-plant yield of the normal population increased with heavier application of phosphorus while that of the alkaline population markedly decreased (Fig. 2). At the lowest concentration of phosphorus, the population from the alkaline soil achieved a higher plant yield than the normal population. The reverse was true at the two higher phosphorus levels. The shoot:root ratio of both populations generally increased as more phosphorus was made available. A significant difference between the two populations under the same treatment was noticed only at the 41 ppm phosphorus level, where the normal population exhibited higher values. Increases in applied phosphorus produced increased concentrations of nitrogen and phosphorus in the shoots of both populations. The phosphorus concentration in the shoots was significantly higher in the normal population than in the population from alkaline soil in all treatments.

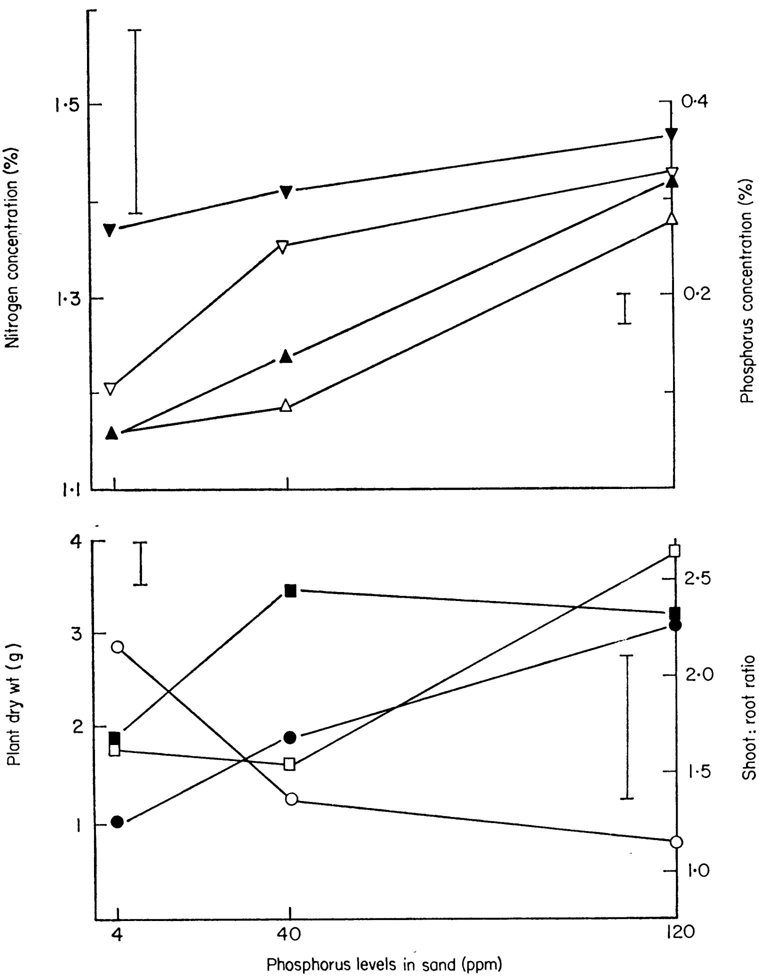


FIG. 2. The responses of the populations from a normal soil (filled symbols) and an alkaline soil (open symbols) to varied levels of phosphorus: ——●——, ——○——, plant dry weight; ——■——, ——□——, shoot:root ratio; ——▲——, ——△——, nitrogen concentration in the shoots; ——▼——, ——▽——, phosphorus concentrations in the shoots. The vertical bars indicate least significant differences.

## *Effects of varied potassium levels*

Increases in applied potassium enhanced the whole-plant yield of the normal population but had no significant effect on the yield of the alkaline soil population (Fig. 3). The yield of the normal population was higher at 78 and 234 ppm potassium than that of the alkaline soil population and the reverse was the case at the 7·8 ppm level. The shoot:root

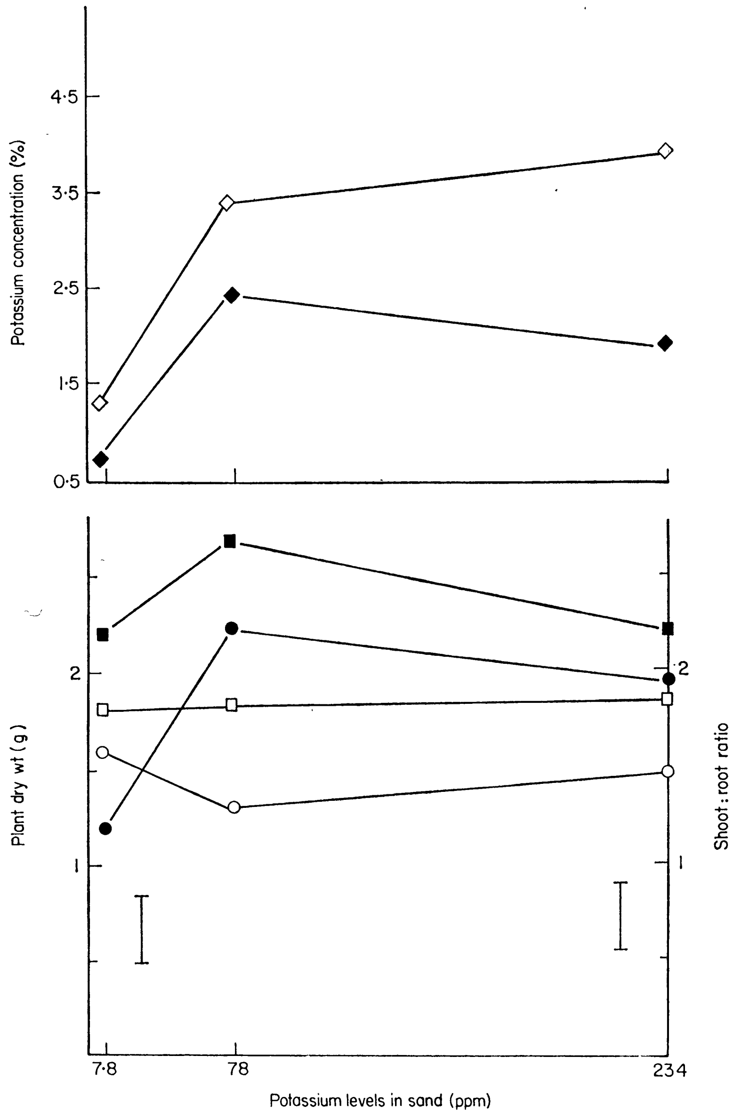


FIG. 3. The responses of the populations from a normal soil (filled symbols) and an alkaline soil (open symbols) to varied levels of potassium: ——●——, ——○——, plant dry weight; ——■——, ——□——, shoot:root ratio; ——◆——, ——◇——, potassium concentration in the shoots. The vertical bars indicate least significant differences.

ratio of both populations was not significantly affected by the different potassium levels; the ratio was consistently higher in all treatments in the normal population.

## DISCUSSION

Alkaline soils are inhospitable media for most plants not only because of the high levels of salts present but also because of the low levels of available nitrogen and phosphorus. Nitrification is greatly reduced in alkaline soils and probably does not occur at very high pH levels (Magistad 1945), while the solubility of phosphates is greatly reduced at high pH (9–10).

The two populations of *Cynodon dactylon* studied here have already been shown to differ significantly in their responses to excess salts (Ramakrishnan & Nagpal 1973). The results presented in this paper show that the population from the alkaline soil is adapted to nitrogen-deficient soils and that nitrogen levels much in excess of those prevailing in the natural habitat of origin produce a marked inhibition of growth. The shoot: root ratio of plants from this population did not increase in response to high levels of applied nitrogen.

Ramakrishnan & Gupta (1972) pointed out that the increase in shoot: root ratio found as a response to increased nitrogen supply by others (Black 1957; Russell 1961; Vose 1962; Bradshaw *et al.* 1964) does not always occur. Chadwick & Obeid (1963) even suggested that nitrogen level might affect the shoot: root ratio of temperate and tropical plants in different ways.

Wiltshire (1973) showed that climax perennial grasses from Rhodesia grew faster with an ammonium source of nitrogen than with nitrate. There is some evidence (P.S. Ramakrishnan & R. Chand, unpublished) that this is true of the population of *C. dactylon* from alkaline soil.

The population from the alkaline soil was found to be susceptible to phosphorus toxicity although it showed no visible symptoms other than stunted growth. The population from the normal soil showed an improved yield at phosphorus levels toxic to the alkaline soil ecotype. Similar phosphorus toxicity has been reported for many species of acid soils (Rossiter 1955; Bingham, Martin & Castian 1958).

The population from the alkaline soil was found to maintain a consistent yield over a wide range of potassium levels whereas the normal population showed increase in growth with increased potassium supply. The great accumulation of potassium in the population from the alkaline soil at higher levels of potassium supply support earlier observations reported by Ramakrishnan & Nagpal (1973). Thus, while earlier studies (Hayward & Wadleigh 1949; Richards 1945; Greenway 1962) related salt tolerance, in part, to an ability to control intake of sodium and other cations, in the case of the alkaline-soil ecotype of *C. dactylon* these elements may be accumulated to high levels before injury becomes apparent.

The physiological basis for the observed differences between the two populations needs to be further investigated. In the case of the normal population improved growth was accompanied by an increased transport of nitrogen, phosphorus or potassium to the shoot (Figs. 1–3). In the case of the population from the alkaline soil transport of nitrogen (or phosphorus) did not behave in a comparable way. Thus, with a halving of whole plant yield between the 63 and 133 ppm N levels there was a doubling of the concentration of nitrogen in the shoots (Fig. 1) and with a reduction in shoot yield to a third between the 4·1 and 41 ppm P levels, there was a three-fold increase in phosphorus concentration in the shoots (Fig. 2). These results show that in these concentration ranges transport of these elements to the shoots is less affected than the processes of growth and is more or less independent of the concentration around the roots.

## SUMMARY

Differential responses to varying levels of available nitrogen, phosphorus and potassium were shown by two ecotypes of *Cynodon dactylon* (L.) Pers., one from a normal soil at Chandigarh and the other from an alkaline soil at Nilokheri, in which the levels of avail-

able nitrogen and phosphorus are very low and the level of available potassium is excessive. There was a positive yield response in the normal soil population to increasing nitrogen and phosphorus supply, but the reverse was found for the population from the alkaline soil. The yield of the normal soil population also increased in response to a moderate increase in the supply of potassium whereas that of the population from the alkaline soil was not significantly affected.

## REFERENCES

**Bingham, F. T., Martin, J. P. & Castian, J. A. (1958).** Effects of phosphorus fertilization of California soil on minor nutrition of citrus. *Soil Sci.* **86,** 24–31.

**Black, C. A. (1957).** *Soil-Plant Relationships.* Wiley, New York.

**Bradshaw, A. D., Chadwick, M. J., Jowett, D. & Snaydon, R. W. (1964).** Experimental investigations into the mineral nutrition of several grass species. IV. Nitrogen level. *J. Ecol.* **52,** 665–76.

**Bradshaw, A. D., McNeilly, T. S. & Gregory, R. P. G. (1965).** Industrialization, evolution and development of heavy metal tolerance in plants. *Ecology and the Industrial Society* (Ed. by G. T. Goodman), pp. 327–434. Blackwell Scientific Publications, Oxford.

**Chadwick, M. J. & Obeid, M. (1963).** The response to variations in nitrogen level of some weed species of the Sudan. *Weed Res.* **3,** 230–41.

**Greenway, H. (1962).** Plant responses to saline substrates. I. Growth and ion uptake of several varieties of *Hordeum* during and after sodium chloride treatment. *Aust. J. biol. Sci.* **15,** 16–38.

**Hayward, H. E. & Wadleigh, C. H. (1949).** Plant growth on saline and alkali soils. *Adv. Agron.* **1,** 1–38.

**Hewitt, E. J. (1966).** *Sand and Water Culture Methods used in the Study of Plant Nutrition.* Commonwealth Agricultural Bureaux, Reading.

**Magistad, O. C. (1945).** Plant growth relations on saline and alkali soils. *Bot. Rev.* **11,** 181–230.

**Piper, C. S. (1944).** *Soil and Plant Analysis.* University of Adelaide Press.

**Ramakrishnan, P. S. (1968).** Nutritional requirements of the edaphic ecotypes in *Melilotus alba* Medic. I. pH, calcium and phosphorus. *New Phytol.* **67,** 145–57.

**Ramakrishnan, P. S. (1969).** Nutritional factors influencing the distribution of the calcareous and acidic populations in *Hypericum perforatum.* *Can. J. Bot.* **47,** 175–81.

**Ramakrishnan, P. S. (1971).** Interaction of soil factors influencing the calcicole-calcifuge behaviour in plants. *J. Indian bot. Soc.* (*Jubilee Vol.*), **50A,** 611–23.

**Ramakrishnan, P. S. & Gupta, U. (1972).** Nitrogen, phosphorus and potassium nutrition of the edaphic ecotypes in *Cynodon dactylon* (L.) Pers. *Ann. Bot.* N.S. **37,** 885–94.

**Ramakrishnan, P. S. & Nagpal, R. (1973).** Adaptation to excess salts in an alkaline soil population of *Cynodon dactylon* (L.) Pers. *J. Ecol.* **61,** 369–81.

**Richards, L. A. (1945).** *Diagnosis and Improvement of Saline and Alkaline Soils.* U.S. Regional Salinity Laboratory, Riverside, California.

**Rossiter, R. C. (1955).** The influence of soil type on phosphorus toxicity in subterranean clover (*Trifolium subterraneum* L.). *Aust. J. agric. Res.* **6,** 1–8.

**Russell, E. W. (1961).** *Soil Conditions and Plant Growth,* 9th edn. Longmans Green, London.

**Snaydon, R. W. & Bradshaw, A. D. (1969).** Differences between natural populations of *Trifolium repens.* L. in reponse to mineral nutrients. II. Calcium, magnesium and potassium. *J. appl. Ecol.* **6,** 185–202

**Turner, R. G. (1969).** Heavy metal tolerance in plants. *Ecological Aspects of the Mineral Nutrition of Plants* (Ed. by I. H. Rorison), pp. 399–410. Blackwell Scientific Publications, Oxford.

**Vose, P. B. (1962).** Nutritional response and shoot/root ratio as factors in the composition and yield of genotypes of perennial rye grass, *Lolium perenne* L. *Ann. Bot.* N.S. **26,** 425–37.

**Wiltshire, G. H. (1973).** Response of grasses to nitrogen source. *J. appl. Ecol.* **10,** 429–35.

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