Factors Controlling Potassium Fertility in Hill Country Pastures

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The steeply undulating pastures of New Zealand hill country have historically been unresponsive to potassium (K) fertilizers. However, decades of nutrient removal and transfer by stock have suggested that K deficiencies may be developing. The onset of K deficiency is difficult to detect in hill country pastures because of the inherent variability in K status across the landscape and within landscape units due to transfer of K by animals. Recent studies in the North Island identified the main factors controlling K fertility in hill country pastures. The work may create opportunities for managing K fertility in hill country using precision application technology.

In New Zealand, it is generally considered that mixed pasture forages should have a K concentration of approximately 2.5 percent for maximum production. This means that in extensive hill country pastures producing approximately 8 tonnes dry matter (DM)/ha/yr, annual plant uptake of K can amount to 200 kg K/ha. Given this high annual requirement for K, understanding the dynamics of K cycling in grazed pasture systems becomes very important.

Surveys were undertaken on two hill country sites in the North Island to determine the relationship between soil K status and slope, aspect, pasture regrowth, spring soil moisture content, and mineralogy. They confirm that three main factors control K fertility of hill country pastures – animal redistribution, micro-relief, and erosional processes.

Animal Redistribution

Although pasture plants require large amounts of K to achieve maximum production, grazing animals such as sheep and cattle require only small quantities to flourish. Most (more than 90 percent) of the K they ingest is excreted, mainly in urine.

On flat land, the spatial distribution of dung and urine is generally random, although areas around gateways, water troughs, and trees or hedges tend to receive a higher return. Therefore, over a period of several years, all areas of the paddock are likely to benefit from the addition of a large quantity of excreted K.

In hilly land, the distribution of dung and urine is not random. Although animals forage for food over the whole area, they rest and sleep on well-defined flatter areas known as camp sites. These are often

Table 1. Soil test results and pasture regrowth within three slope zones in two hill country pastures.

	Ground slope class, degrees					
	20 to 50		10 to 20		0 to 10	
	Mean	C.V.	Mean	C.V.	Mean	C.V.
Exchangeable K, mg/g	0.14	44%	0.37	78%	0.51	59%
Pasture regrowth, kg DM/ha	880	40%	1430	37%	1480	27%
Number of results	31		11		17	

in sheltered spots in the lee side of ridges. There is, therefore, a systematic transfer of K from the sloping areas of the paddock to the flatter areas (**Table 1**).

Relief

Hilly land, by its very nature, has areas of differing slope and aspect. The rugged landscape in which one of the surveys from this study was conducted is illustrated in the photo. Areas facing the sun are warmer than areas on the shady side of the hill. Rainfall tends to run off steep spurs and ridges and collect in hollows and flatter areas. These contrasts in relief and microclimate can result in three- and four-fold differences in the amount of pasture grown in different areas of the paddock. This will have major implications for the amount of K taken up by the pasture plants and the amount transferred away by grazing animals.

Grazing stock favor flatter ground in hilly pastures, particularly the ridge-tops.

These differences in soil water status, temperature, and plant growth also affect the chemistry of K within the soil. Young soils of sedimentary origin are generally well supplied with available K. As time goes on, the soils become more weathered, and the reserves of available K become depleted through grazing or other crop removal and through leaching. The varied terrain in hill country means that all of these processes are occurring at different rates in different parts of the landscape. Thus, the soil K status can be expected to vary in a complex way. For example, this study showed that non-exchangeable K content had a strong positive relationship with mica content. But it was also related to aspect and spring soil moisture, suggesting that the microrelief was able to influence the weathering of clay minerals due to temperature and moisture effects.

Erosion Processes

The final complicating factor in New Zealand hill country relates to the age of the soil and soil renewal through erosion. As noted earlier, young, undeveloped soils on sedimentary parent materials tend to have large reserves of available K. As soils on flat land weather and are cropped year after year, these reserves become depleted, and K fertilizers are required to enable farming to be sustainable. On steep slopes, however, erosive processes constantly remove the topmost layers of soil and expose the less weathered parent material beneath. This is a disadvantage for nutrients like nitrogen (N) that are stored mainly in the organic matter in the topsoil. But for K that originates in the soil minerals, this constant exposure of fresh, unweathered material can maintain soil reserves at a high level. Once again, the extent of these erosion processes and the soil K status will vary markedly across the landscape.

As a result of all these interacting processes, many hill country pastures contain areas that are deficient in K and will respond to added fertilizer, but also contain areas that have ample reserves of soil K and are unlikely to respond to fertilizer K. This variability in soil K levels across the landscape may mask a developing deficiency for many years. What is needed is an understanding of the processes that are affecting the distribution of K within the farming system, so that areas of the landscape that are likely to be most deficient can be identified. It is in these areas that soil samples should be collected and trials conducted to assess the degree of response to K fertilizer addition.

This study has concluded that developing K deficiency will first be apparent in steep areas of the field where the micro-relief results in collection of moisture. In these sites, plant uptake is enhanced, weathering of micaceous minerals is more rapid, and grazing will transfer K away from steep slopes towards the flatter ridge tops. To manage such a complex system successfully, it is necessary to recognize the whole spectrum of K availability that exists in the landscape – and not resort to a single value such as an average. This concept is now well established in the "precision farming" technologies associated with cropping on flat land, but is new to the management of extensive hill country pastures.

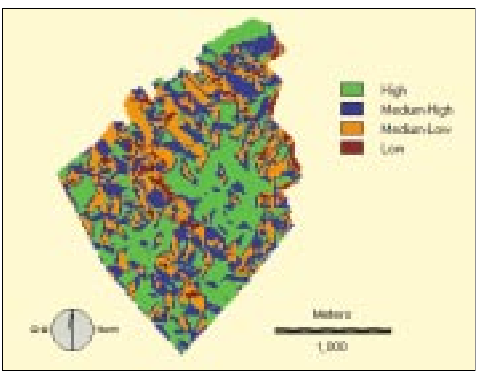

Figure 1. Fertilizer requirements vary with north- or south-facing slopes, steepness, and other factors.

The first step in formulating a fertilizer program is to consider the limits imposed by the application technology. Most fertilizer application in hill country is from the air. This limits the precision of application. However, the soil pattern and the nature of the topography may still allow different fertilizers – or different rates of the same fertilizer – to be applied to different areas. An example might be differentiating between north- and south-facing aspects or slope categories (**Figure 1**). If one aspect or slope category is likely to respond to K fertilizer and the other is not likely to respond, then the ability to differentially apply fertilizers will greatly improve the economics of fertilizer use.

(continued on page 31)