PASTURE PLANT, WATER-TABLE INTERACTIONS ON MANAWATU SANDY COUNTRY

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Abstract

Movements of a water-table (WT) underlying a site in the Manawatu sand country were measured over 18 months and related to soil moisture levels and pasture performance across a soil toposequence. The WT made an effective contribution to plant growth in summer only when in contact with the topsoil. Stabilizing WT levels by drainage and outlet control appears to offer the best approach to increased plant utilization of the WT on the more elevated soils.

INTRODUCTION

MANAWATU sand country consists of shallow basins between long, stabilized dunes which lie at right-angles to the coast. A continually varying water-table (WT) underlies the area and interacts with this topography to produce an intermixture of drought-prone and waterlogged soils. Small differences in elevation can cause large differences in soil properties and soil water supply which are reflected in pasture composition (Rumball, 1978). It is usually impracticable for farmers to fence and manage these areas separately. Also, draining to reduce waterlogging of low areas in winter tends to increase the area affected by drought in summer. Information is needed as to both positive and negative effects of the WT on pasture plants and how these can be modified.

Water-table movement and its effects across a sequence of soils were studied on Flock House farm over 18 months. Information was also gathered on reaction to and utilization of water-table moisture by various pasture species.

INHERENT SOIL TYPE DIFFERENCES

The trial site was a 40 m broad transect over a 60 m long toposequence which included a "basin" (Pukepuke black sand), a "terrace" (Himatangi sand), and a dune (Foxton dark grey

*Work carried out when with Ministry of Agriculture, Palmerston North.

TABLE 1: SOIL PROPERTIES

	Pukepuke		*Himatangi*		*Foxton*	
	Topsoil	*Subsoil*	*Topsoil*	*Subsoil*	*Topsoil*	*Subsoil*
Depth (mm)	200		170		120	
Clay < 2μ (%)*	5.0	0.3	1.9	0.6	1.6	0.5
Org. C (%)	4.2	0.3	3.5	0.2	2.1	0.3
Total N (%)	0.3	0.02	0.2	0.02	0.14	0.02
C E C (m.e. %)	12.3	2.8	9.7	2.7	6.1	2.3
Avail. WHC (mm)	63	27†	42	23†	31	17†

*Claridge (1961).
†Equivalent to depth of topsoil.

sand), (Cowie and Hall, 1965). The WT occasionally rose above the lowest area. Average elevation of the Himatangi soil was 0.4 m above the Pukepuke and 1.2 m below the Foxton.

Soil properties which mainly determine water-holding and nutrient-supplying capacities were measured down each profile (Table 1).

In all profiles, subsoils contained less clay fraction and OM than topsoils and so both CEC and available water-holding capacity (WHC) per unit depth were much lower. Among soil types, as elevation increased, there were declines in topsoil depth, clay and OM contents, CEC, and available WHC. No such trend occurred among subsoils.

WATER-TABLE CONTRIBUTIONS

Water-table levels and soil water contents were measured at about IO-day intervals. The WT fell rapidly in late spring (up to 15 cm per week) and rose gradually during winter to a maximum in early October. Weather conditions modified this general pattern and WT levels responded quickly even to light rains. Height ranges in successive years were 1 .0 m and 1.2 m.

Pukepuke topsoil was above field capacity (FC) for 18 weeks of winter/early spring. Water content fell with WT level but, even with the loss of its contribution in late summer, storage capacity was sufficient to maintain topsoil above wilting point (WP) and plants in a green condition throughout. Himatangi topsoil was replenished when the WT rose to within 60 cm of the surface, but the effect was fleeting and for 9 weeks and 7 weeks in successive warm seasons it was near or below WP. Foxton topsoil was at WP 2 to 3 weeks longer than the Himatangi each summer. Here the WT made nil contribution.

TABLE 2: CHANGES IN PASTURE CONDITION AND SOIL WATER CONTENT BETWEEN PUKEPUKE AND HIMATANGI SOILS DURING RAPID WT FALL (MID-DECEMBER)

	Pasture Condition			
	Green		*Wilting*	*Brown*
Core positions	1	2	3	4	5
Distance (m)	0	6.2	11.2	11.8	13.7
Elevation (cm)	0	8	30	41	53
Depth (cm) :	*Soil Waler % w/w*				
topsoil—					
0-5	48	37	25	7	3
15-20	28	30	18	4	2
subsoil—					
20-25	11	10	7	4	2
30-35	12	9	6	5	4
40-45	20	17	8	6	4
WT depth (cm)	58	66	89	99	112

The significance that even small differences in elevation can have on soil water supply is illustrated by a sampling transect taken during an early summer period of rapid moisture depletion (Table 2). Over an elevation difference of 53 cm the topsoil fell from near FC to WP and the subsoil from saturation to below WP. Other data indicate a rise of 24 to 32 cm for the capillary fringe in the subsoil. Although both horizons dry out simultaneously, the upper subsoil tends to reach WP before the topsoil.

Efficiency of rainfall interception also differed markedly among these soil types. Infiltration measurements were made in March at maximum soil dryness. In one hour the Pukepuke absorbed 22 mm of which 41% was retained in the topsoil. In similar time, the drier Himatangi and Foxton soils absorbed 200 to 250 mm but retained only 19% and 14%, respectively, in the topsoils. In the latter case, narrow drainage channels formed so that much of the upper profile remained unwetted. Whereas the infiltration rate fell with time on Pukepuke, it increased rapidly up to 45 minutes on the upper soils, indicating some degree of water repellence near the soil surface.

PLANT PERFORMANCE

If the range of soils is to have common grazing it would be desirable to use pasture species of sufficiently wide adaptability to perform well across the habitat range. Three legumes (Huia white clover, Turoa red clover, Wairau lucerne) and four grasses

(Ruanui perennial ryegrass, S 170 tall fescue, Australian commercial ***Phalaris aquatica,*** and Apanui cocksfoot) were spring-sown in duplicate plots across the toposequence. Spray irrigation was used until late December to ensure good establishment, maintenance fertilizer was applied, and sheep or young cattle grazing followed by trimming occurred at 6- to S-week intervals. Dry matter yields were measured from small quadrats in plot centres and average growth rates calculated for four periods over the 18 months of measurement — ***i.e.,*** establishment phase, two warm seasons, and the in-between cool season (Fig. 1).

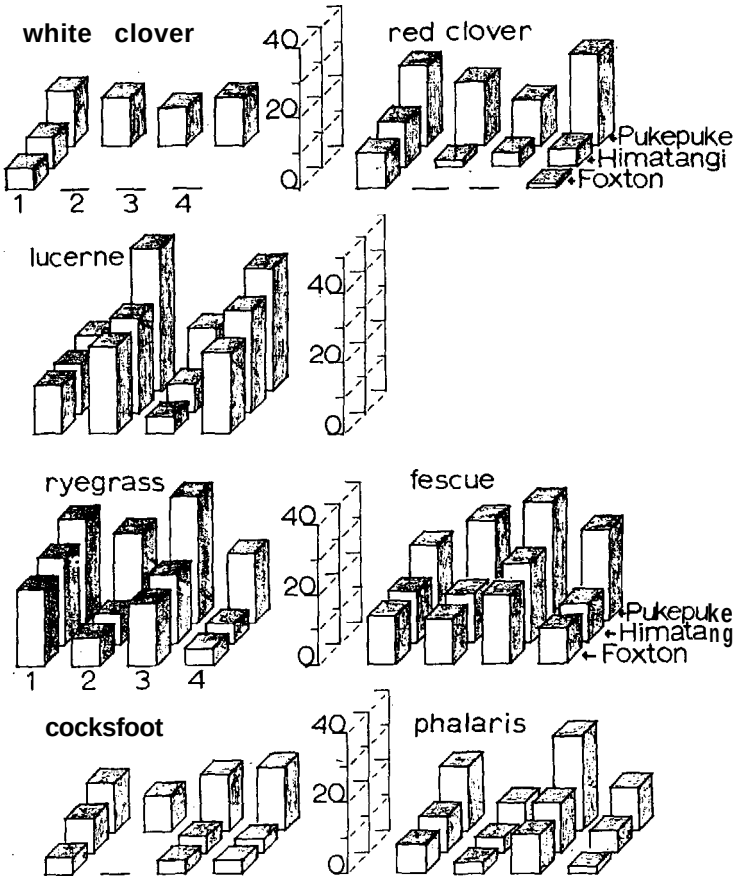

FIG. ***1: Average growth rates (kg*** *DM/ha/day)* for 7 ***species*** on three ***soil types. Period 1 establishment,*** *30/10/70* ***to*** *20/12/70;* ***2,*** *30/12/70 to 26/4/71;* 3, *27/4/71* ***to*** *25/11/71;* ***4,*** *26/11/71* ***to*** *13/3/72.*

During the 10 weeks of adequate soil moisture all species established well across the transect. Rapid onset of drought conditions occurred on the two upper soils from mid-January causing complete mortality of white clover, high mortality of red clover and cocksfoot, lower losses of phalaris, and negligible losses of lucerne, ryegrass, and fescue.

White clover was the most sensitive to both overwet and overdry soil conditions and quickly became confined to a narrow zone in the middle Pukepuke which closely coincided with its distribution outside the trial. Red clover grew well on the lower soil and surviving plants on the upper soils produced better in the second year. Lucerne had relatively high persistency and production throughout the range of soil conditions. At the lower end, plants over a small area were killed when the WT was above the crown for 4 days but where the WT was just beiow the ground surface plants were apparently unharmed. In the first growing season, Pukepuke lucerne outyielded Himatangi and Foxton lucerne by 52% and 64%, but in the second this advantage fell to 21% and 49%, respectively. It is likely that the smaller variation was due to plants in the latter soil types being able to exploit more of the subsoil water supply in the second year even though drier topsoils still markedly reduced growth.

Observations on lucerne root system were made by means of a soil window (1.2 m wide by 0.9 m deep) located at the transition between Pukepuke and Himatangi soils, and by excavations at intervals along the transect. During establishment, high WT levels caused many lucerne plants at the lower end to produce a much-branched system of major roots which contrasted with the strongly tap-rooted character of plants not so affected (Fig. 2). The lucerne root in the soil window reached 72 cm 10 weeks after planting, not managing to keep up with the falling WT but producing many fine branching roots within the capillary fringe. As the WT rose during the following winter, the fine roots generally died and there remained the major roots with a distinct zone of branching, stubby, secondary roots. Next growing season, fine roots were again concentrated in the topsoil and that zone of the subsoil where the capillary fringe occurred during root formation.

Among the grasses, ryegrass was quickest to establish and it persisted well even though yields on the elevated soils were invariably lower — and much lower over the two summer periods. Fescue was the best performer in terms of production and persistency and least affected by soil variation. It was also least

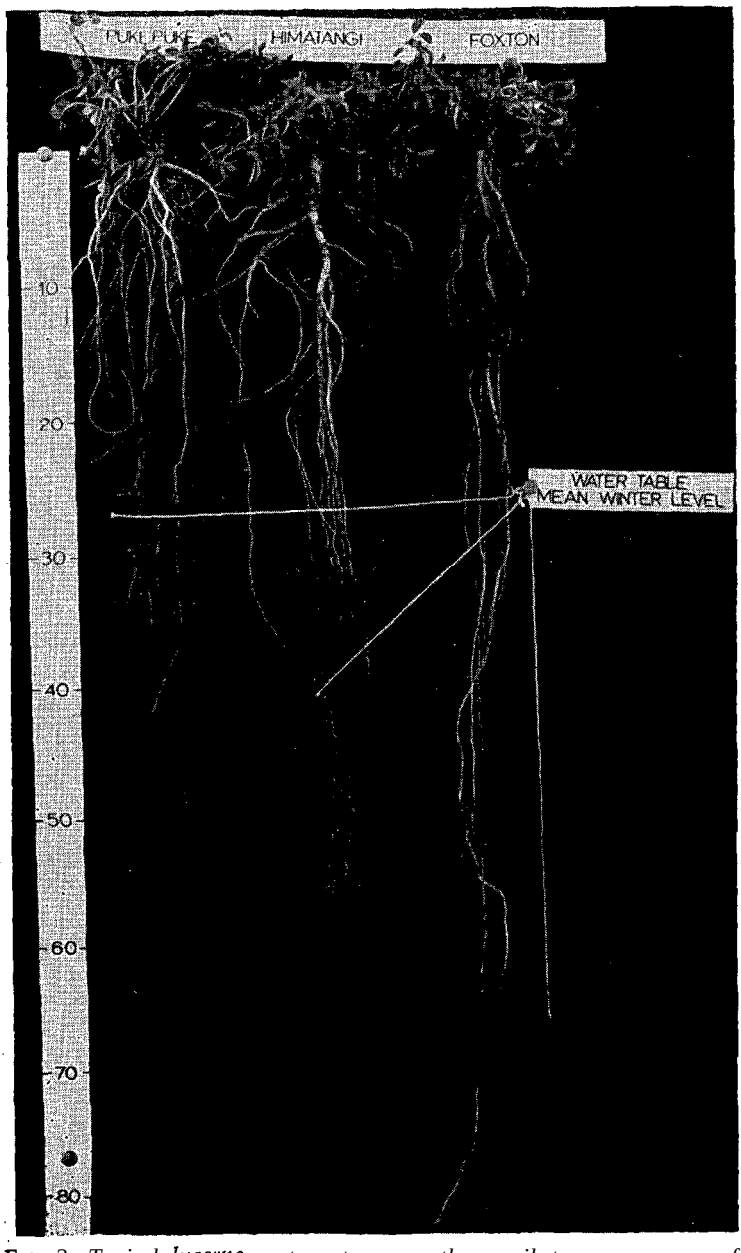

FIG. 2: *Typical lucerne root systems on three soil types one year after sowing.*

acceptable to stock. As for red clover, only isolated plants of cocksfoot survived the first summer on the upper soils but these performed much better in the second, indicating that the period of establishment may not have been sufficient for this species. Phalaris persisted reasonably well but was markedly dormant on all soils for much of the warm season. As indicated by the soil window, the root system was initially faster growing than that of ryegrass (84 cm in 10 weeks as compared with 69 cm), roots were thicker, and there was less renewal of major roots between years — the latter characteristic being related to differences in rate of tiller turnover.

DISCUSSION

Differences in persistency and yieid can be explained in terms of speed of establisment or general adaptation to drought. Of the better adapted species, none was able to continue good growth through the dry season even when fine roots were observed in moist subsoil. There are two obvious explanations. First, WT movement was continuous, rising rapidly after rain and falling more slowly so that root systems near the capillary zone would need to make continual adjustment. Secondly, N concentrations in subsoils were very low and drying of topsoils would remove the major N source to grasses and possibly other nutrients to legumes. Thirdly, maximum miday temperatures up to 53" C were recorded at the surface on the dry upper soils compared with a maximum of **33"** C for the Pukepuke soil.

In the absence of WT influence, cool season replenishment of subsoil water shortage was poor — e.g., the Foxton subsoil (to 1.7 m) did not exceed 5% water content even at the end of winter and for most of the time was close to WI'. Therefore deep-rooted, drought-tolerant plants, theoretically (like lucerne) able to maintain contact with the WT or at least exploit a large soil volume, may continue growth longer but will still be subject late in the summer to moisture/nutrient deficiency. More success might be gained from hardy subtropical stoloniferous or rhizomatous grasses, as for instance varieties of *Cynodon* or *Digitaria.* Such plants can better withstand high temperatures and low moisture than temperate species and could be expected to maintain more ground cover and respond readily to summer showers. However, greater summer production could be offset by suppression of cool season growers. A third type of plant material is the drought-avoiding Mediterranean group of species

such as annual clovers and *Seradella.* Observations indicate high seedling mortality of some annuals when dry periods follow late summer rain. This might be avoided with better adapted varieties.

Levelling the topography by moving soil from dunes to low areas is an obvious approach to improving soil water status over large areas. Because the elevation difference between overwet and overdry is small, and because of the large annual range in WT height, benefits are likely to be marginal. A better approach would be to minimize fluctuations in, or ideally to stabilize, WT levels. Perennial plants could then adjust root systems to a continually moist zone. This would allow more efficient response to topsoil moisture and nutrients made available by summer rain. By maintaining a better ground cover, soil temperatures would be reduced and so probably would the tendency for topsoils to develop water-repelling properties.

On this site, the fast WT response to local rainfall and the fact that during periods of rapid WT change measurable hydraulic gradients developed between the ends of the 60 m transect suggest a localized WT basin and a good chance of some outlet control. A number of farmers who have used surface or deeper drains to reduce peak WT levels have found that blocking these drains in summer can reduce WT fall. However, research is needed to better determine underground drainage patterns and particularly to identify and relate outlets to river, sea, or aquifer levels. .

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