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REVISIÓN CIENTÍFICA

NOTA DE LA DIRECCIÓN:

Acabábamos de pedir al Dr. Raymond Wilkie Brougham una colaboración para la Revista PASTOS sobre **"pastos para nuestro mundo"** cuando le sorprendió la muerte. Este título era, precisamente, el lema del XVII Congreso Internacional de Pastos, celebrado en 1993, del que fue su Presidente. El artículo del Dr. Warwick Harris trata de ser un modesto homenaje al hombre, de gran categoría humana y científica, que mostró por todo el mundo su vocación por el estudio de los pastos.

Orientación para el lector: En Nueva Zelanda, la primavera comienza en Septiembre, el verano en Diciembre, el otoño en Marzo y el invierno en Junio.

THE CONTRIBUTIONS OF DR. RAYMOND WILKIE BROUGHAM TO GRASSLAND SCIENCE AND MANAGEMENT

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SUMMARY

The contributions to grasslands research and practice of the internationally notable New Zealand Scientist, Dr Raymond Wilkie Brougham are reviewed. He made significant contributions to the fundamental understanding of processes in pasture establishment, pasture growth particularly its relationship with leaf area and light interception, and to grazing management effects on the botanical and genetic composition of grassland communities.

Application of his understanding of the requirements of pasture management was demonstrated in a series of farmlet studies that realised very high levels of dairy beef production. In New Zealand, and internationally later in his career, he was very successful in transferring his concepts of management to grasslands farmers. In retirement he made very important contributions to the New Zealand amenity and sports turf industry.

He played a very significant administrative role in shaping the direction of grassland research and application in New Zealand, especially when Director of Grassland Division from 1971 to 1985. His concepts of organisational structures that met both national and regional needs for research and extension were applied worldwide in his role as an international consultant. As President of the XVII International Grassland Congress he led the development of a conference format that encouraged participation for effective presentation and discussion of grassland research and application.

Key words: Pasture establishment, Light interception, Pasture composition, Research administration.

INTRODUCTION

As one of many people helped by Dr. Ray Brougham (Fig. 1) in their involvements with the development and use of grasslands I am privileged to accept the request from

PASTOS to write a review of his work. Inevitably my review will draw most intensively on the period from 1959 to 1982 when I worked closely with him as a research worker in pasture ecology. Others who worked with him at other places, at other times, and in ways different from those that were the basis of my association, would bring in different perspectives and introduce other aspects of his works with which I am not familiar.

My review draws most directly on his published works. The bibliography contains the most comprehensive listing of these publications that I have been able to compile. Not all of the publications are referred to in the text, but they are listed to illustrate the extent to which Ray Brougham made the effort to present, interpret and discuss the practical applications of his results to grassland farmers, advisors and research workers. The figures chosen to illustrate his research results are copied without alteration from the original publications. Although these mostly use imperial measurements, it is the relative rather

Figure 1.- Dr. Ray Brougham.

than the absolute differences of the responses observed in his experiments that are of most interest.One of Ray Brougham's strengths was the ability and willingness to communicate with people at the individual level both orally and by letter. Undoubtably a wealth of information and wisdom rests in these communications. I hope this review will act as an encouragement to those whose work on grasslands was influenced by Ray Brougham to record their associations with him and pass these records on to the grassland workers of the future.

THE EARLY YEARS

Ray Brougham was born in Palmerston North in 1926 and remained a loyal citizen of that city until he died on October 24 1993. Palmerston North is situated in the south western part of the North Island of New Zealand in an environment that is regarded as one of the most favourable for pasture production in the world. The city developed as a servicing centre for the dairy, cattle and sheep farms on the productive pastures of the formerly forested plains and hill country of the Manawatu region.

Development in the 1920's of two institutions that have been of key significance to agricultural research in New Zealand raised the status of Palmerston North above that of many other New Zealand towns and cities that developed as rural servicing centres. These institutions provided the opportunity for the career path that Brougham followed, and he became a leading advocate of their roles later in his life. They were Massey Agricultural College founded at Palmerston North in 1926, and the New Zealand Department of Scientific and Industrial Research (DSIR) established in the same year. In 1928 a Plant Research Station was established in Palmerston North as a joint undertaking of the New Zealand Department of Agriculture and DSIR. This organisation formed the foundation of several DSIR Divisions, including Grasslands Division. Grasslands Division retained its headquarters in Palmerston North when it was established in 1936 with Sir E. Bruce Levy as the first Director (Atkinson, 1976). Massey Agricultural College, now Massey University, and Grasslands Division which was incorporated as part of the Agresearch Crown Research Institute in 1992, gave Palmerston North international status as a centre of excellence in grassland research.

Brougham's entry into grasslands research was by chance. He completed his secondary school education at Palmerston North Boys' High School and was successful in gaining entry for officer training at the Military College, Duntroon, Australia but did not take this up. He worked as a clerk at the local power board in 1945. It was during this time that an encounter at a vehicle service station in Palmerston North between his father and either Levy or Dr Peter Sears, then Head of the Pasture Ecology Section of Grasslands Division, provided the opportunity for Brougham's entry in to grasslands research as cadet/technical assistant in February 1946. He was supported for study at Canterbury University College and graduated with a B. Sc. from the University of New Zealand in 1950. In 1963 he was awarded the degree of D. Sc. by Canterbury University.

Both Levy and Sears were key influences on the development of Brougham's ideas and philosophy about grassland ecology and production. Levy's broad understanding of grassland ecology, presented in his book "Grasslands of New Zealand" (Levy, 1970), still stands as an authoritative integrated account of New Zealand's grassland ecology and production. It was from Sears and those that worked on his studies of pasture growth and soil fertility (Sears, 1953a, b, c; Melville & Sears, 1953; Sears & Evans, 1953) that Brougham would have learned about the practical aspects of grassland experimentation and the fundamental function of nitrogen fixation by clovers in New Zealand pastures. It is in this series of studies that the name R. W. Brougham first appears in the grassland science literature in an acknowledgement for technical assistance.

PASTURE ESTABLISHMENT STUDIES

Two important factors influencing the requirements for research on pasture establishment in New Zealand after the Second World War were the expansion of intensive grassland development in to areas with climates and soils more marginal for pasture production, and the availability of new herbage cultivars. An important facet of Sears work was pasture establishment on the pumice soils of the central volcanic plateau of the North Island (Sears *et al.*, 1955). At about the same time as Sears' study Brougham began experimentation in his own right by undertaking studies that focused on the use of short-rotation ryegrass in the establishment of pasture on the fertile soils of the Grasslands Division research station at Palmerston North.

Short rotation ryegrass, (*Lolium perenne* X *L. multiflorum*) also known as H1 ryegrass and later as `Grasslands Manawa', marked a significant step in the the progress of forage plant breeding in New Zealand. It was bred by Dr Lionel Corkill (1945), who became Director of Grasslands Division when Sears died in 1963, and continued in this role until his retirement in 1971 when Brougham was appointed Director. An important function of the Pasture Ecology Section, of which Brougham was a member, was to evaluate and introduce new herbage cultivars into grazing management systems. This could be done as a routine agronomic evaluation. However I surmise that in being given the task of evaluating short-rotation ryegrass, Brougham was motivated more by gaining insight of the mechanisms that caused the cultivar to perform in a particular way, rather than just recording that performance.

The results of these pasture establishment studies were first reported at the first of Brougham's many appearances on the platform of the annual conferences of the New Zealand Grassland Association when the fourteenth of these conferences was held at Timaru in 1952 (Brougham, 1953). Dr Ken Mitchell and Mr Arch Glenday, both of whom had a marked influence on his work, also spoke at this conference (Glenday, 1953;

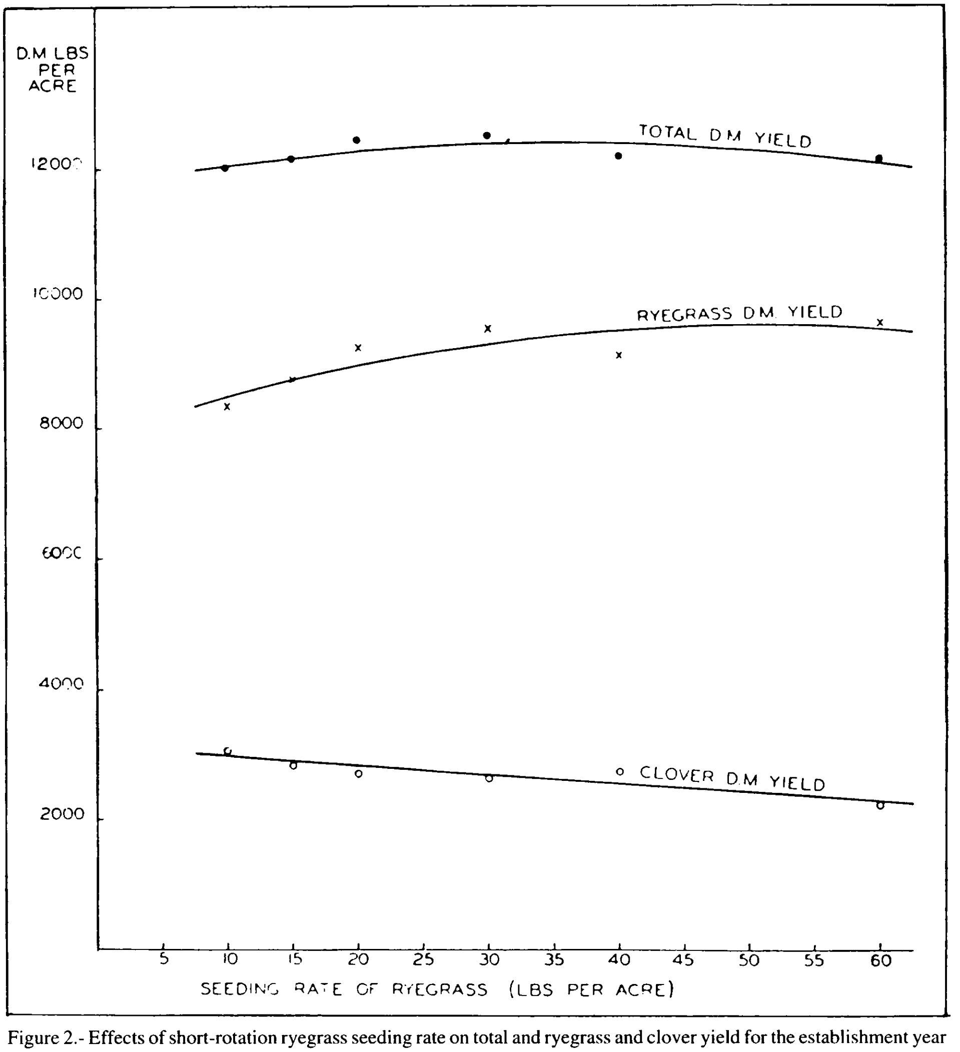

Figure 2.- Effects of short-rotation ryegrass seeding rate on total and ryegrass and clover yield for the establishment year of a pasture (Brougham, 1954a).

Figura 2.- Efecto de la dosis de siembra del raigrás híbrido sobre la producción del raigrás, del trébol y total del año de establecimiento de una pradera (Brougham, 1954a).

Mitchell, 1953). Insights gained by Mitchell through study of the whole plant physiology of pasture grasses and clover were important in the interpretation of the results Brougham gained from his field experiments, and Glenday played a key role in the design and statistical analysis of the experiments he undertook.

The pasture establishment studies, published as a series of four papers in 1954, contributed to what continue to be standards for the formulation of the seed rates and species proportions for high producing ryegrass-white clover pastures in New Zealand. The first study (Brougham, 1954a) measured changes of seedling populations, effects on plant development of the grass and clover components, and herbage yields for the year following autumn sowing when the seeding rate of short-rotation ryegrass was varied in seven steps from 0 to 67 kg/ha, while the rates of red clover (*Trifolium pratense*) and white clover (*T. repens*) were held constant at 4.5 and 3.4 kg/ha respectively. High short-rotation seed rates provided more ryegrass and total yield initially but suppressed clover yield. This reduced clover yield resulted in a reduction of nitrogen available to the grass, reducing ryegrass yield at higher seeding rates later in the year. Consequently for the year the optimum result in terms of seed cost, grass-clover balance, weed control and yield was obtained with a short-rotation seed rate of about 20 kg/ha (Fig. 2). The study showed the compensating effects caused by competition for light of tiller number per established seedling and tiller weight on the unit area yield of the pasture.

The second experiment (Brougham, 1954b) investigated grazing height as a management option in the establishment of short rotation ryegrass-clover pasture. Short rotation ryegrass sown in autumn with red and white clover at rates of 17 or 45 kg/ha was initially grazed when the pasture height reached either 7.5 or 22.5 cm. Later these grazing heights were reversed. Grazing at a herbage height of 7.5 cm enabled good clover establishment irrespective of grazing height whereas clover growth was suppressed to the extent that it caused unthrifty ryegrass growth in spring with the combination of high ryegrass seed rate and grazing at 22.5 cm. Brougham concluded that sowing short-rotation ryegrass at the low seed rate was advantageous as it allowed more latitude in the grazing management used without adversely affecting clover establishment.

Effects on short-rotation ryegrass and clovers by the inclusion of barley as a cover crop for winter green feed was investigated in a third experiment (Brougham, 1954c). While barley boosted winter yield, its inclusion in the seeds mixture depressed ryegrass and total yield but increased clover in spring. However by summer the effects of barley were not apparent. These responses were explained by reference to grazing height effects on competition for light and effects of clover suppression on available soil nitrogen. The fourth experiment (Brougham, 1954d) examined interactions between the components of what became a standard mixture for medium to long term pastures on fertile soils from the

1950's through to the 1970's - `Grasslands Ruanui' perennial ryegrass, `Grasslands Manawa' short-rotation ryegrass and red and white clover. This study showed that short-rotation was more aggressive than perennial ryegrass during the establishment phase causing suppression of both weeds and clovers. It pointed to the need to define the appropriate balance between the content of the two ryegrasses in mixtures and was the forerunner to experiments that followed changes in the genotypic structure of ryegrass based pastures.

PASTURE GROWTH RATE STUDIES

In 1953 Brougham began a series of intensive studies of the growth of short-rotation ryegrass and clover pasture, collecting data to construct the curves of herbage dry matter production after defoliation. The first of these studies (Brougham, 1955) obtained curves for total herbage and ryegrass growth in spring that were sigmoid with three phases over the nine week growth periods. The second linear phase provided a constant daily increment of dry matter of about 170 kg/ha for about five weeks. This result led to the suggestion that maximum herbage production from the pasture could be maintained if herbage height was kept in the range that occurred during the five week period i.e. 12.5 to 35 cm.

Brougham next directed attention to the growth of short-rotation ryegrass based pasture over the late autumn to early spring period (Brougham, 1956a). This study related to the practice of *in situ* conservation by spelling pasture in autumn to allow the saving of herbage to be fed to stock during the period of low pasture growth in winter and early spring. The experiment measured the accumulation of herbage from four commencement dates of spelling at three week intervals, starting from 1 April (12 weeks before the winter solstice). Apart from the last spelling period the growth curves were sigmoid (Fig. 3). The initial phase of growth became extended from about 5 to 10 weeks as the commencement of spelling was delayed into the winter. For the first three spelling dates the second linear phase lasted about three weeks but the growth rate decreased as the spelling date was delayed. Consequently the highest ceiling yield was obtained from the first spelling date. This treatment provided little further yield after nine weeks whereas the treatment spelled from this date yielded 1350 kg D.M. during the 9th to 18th week. From these results Brougham concluded that maximum yield during the 16 weeks of the late autumn to early spring would be obtained with spelling intervals no longer than six weeks. Less intensive defoliation by grazing during this period was also recommended as a way to reduce the length of the initial growth phase.

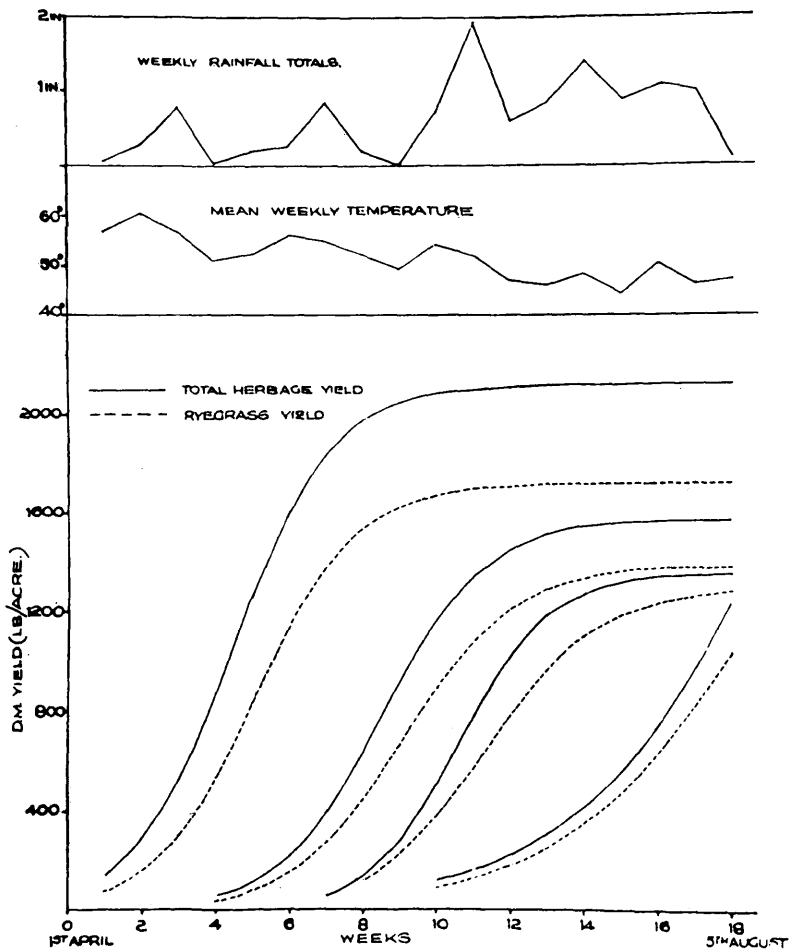

Figure 3.- Fitted logistic regrowth curves for the dry matter yields for total herbage and ryegrass yields from four dates of spelling in autumn and winter with associated variation of mean weekly air temperatures and rainfall totals (Brougham, 1956a).

Figura 3.- Curvas logísticas ajustadas a la producción de materia seca, total y del raigrás, del rebrote, en cuatro fechas del otoño e invierno, y variación semanal asociada de la temperatura media del aire y de la lluvia total.

EFFECTS OF SEASON AND WEATHER ON PASTURE PRODUCTION

The technique Brougham used in his pasture growth studies was developed in collaboration with Glenday (1955, 1959) and involved layouts that provided replication in time as well as space to allow separation of temporary weather variations on growth. This enabled derivation of pasture growth curves with the influence of short-term weather fluctuations removed. The approach was also used to identify the importance of the specific effects of light levels, temperature and rainfall on pasture growth rates.

Brougham (1959a) using the technique derived a set of annual growth curves of a short-rotation and white clover pasture (Fig. 4). The average daily growth rate of the pasture ranged from 10 kg DM/ha in winter to 135 kg DM/ha in early summer. It was estimated that the potential annual yield of the pasture on the fertile soil of the site was 24,000 kg DM/ha (Fig. 5). This yield became a bench mark to measure progress in improvement of pasture production in New Zealand and to explain the losses of yield caused by factors such as treading and summer drought. The study also highlighted the seasonal switch from ryegrass to white clover dominance. In discussing this switch, Brougham probably underestimated although did not overlook the importance of flowering in causing the reduction of short-rotation ryegrass growth in summer. Defoliation in relation to both its impact on leaf area index and light interception and reproductive growth was an important subject of later detailed sward studies aspects of which are reviewed by Korte & Harris (1987). Brougham's (1959a) study showed that in winter the growth of the dominant ryegrass component was influenced by both temperature and light levels, whereas in summer fluctuations of white clover growth were mainly associated with temperature variation.

A related study examined the effects of weather fluctuations on the daily rate of growth of pure stands of perennial and short-rotation ryegrass and cocksfoot (Brougham & Glenday, 1969). The marked differences of seasonal growth rates recorded were attributed to seasonal changes of temperature and light, and variation of summer rainfall. Effects of daily changes of weather on pasture growth were also detected, in some cases showing time-lag correlations.

The untimely death of Arch Glenday before publication of this work deprived Ray Brougham of a person who was a very important aide in his experimental work. Glenday was an excellent and patient teacher and applicator of biometrics and statistics at a time before modern computer technologies removed most of the drudgery of applying these disciplines to experimental work.

LEAF AREA, LIGHT INTERCEPTION AND CHLOROPHYLL CONTENT

Detailed examination of the effects of intensity of defoliation on pasture regrowth was made in an experiment undertaken in spring 1954 (Brougham, 1956b). Short-rotation and clover pasture was cut back from 23 cm to heights of 2.5, 7.5 and 12.5 cm and the regrowth of these treatments measured for 32 days. Changes of leaf area and light

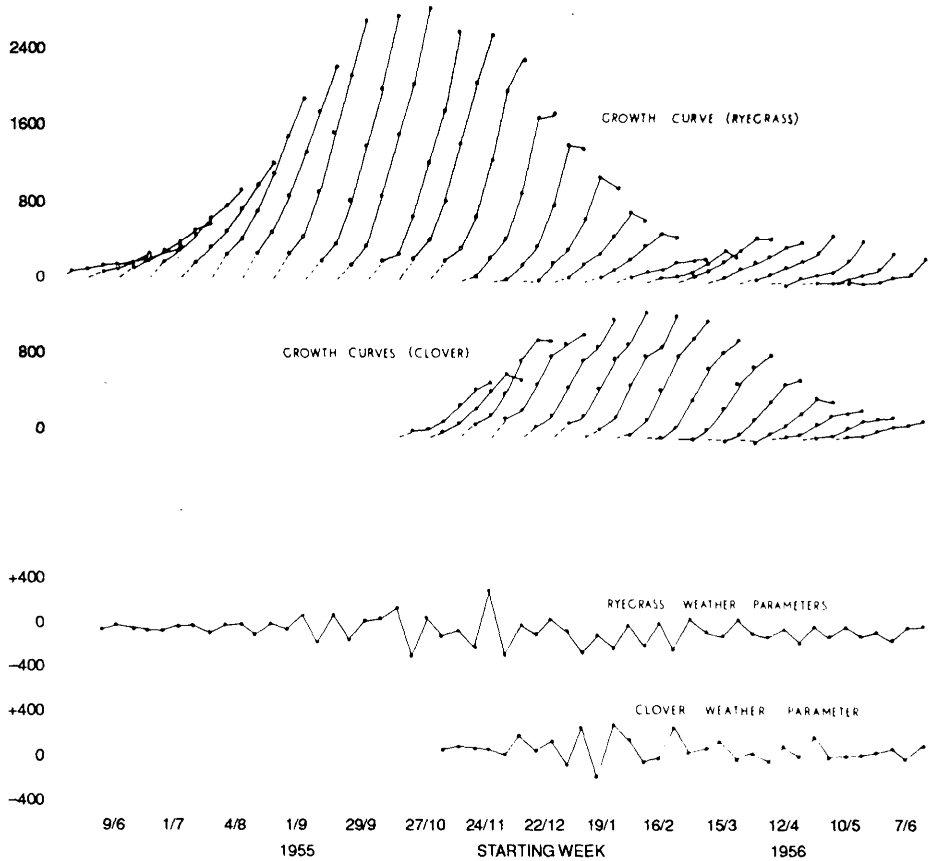

Figure 4.- Ryegrass and clover yields separated into growth curves for a smoothly changing climate from a series of defoliation dates in the course of a year at Palmerston North, New Zealand. The weather parameters show growth attributable to weekly fluctuations in weather. (Brougham, 1959a).

Figura 4.- Producciones del trébol y del raigrás, separados en curvas de crecimiento para un cambio suavizado del clima, correspondientes a una serie de fechas de aprovechamiento en el transcurso de un año en Palmerston North, Nueva Zelanda. Los parámetros climáticos muestran el crecimiento atribuible a fluctuaciones semanales del tiempo (Brougham, 1959a).

interception that occurred during the regrowth of the treatments were also recorded. This was the first time that the relationships between light interception, leaf area and the rate of regrowth were studied for pasture. Full light interception was attained when the area of leaf of the pasture per unit area of ground (leaf area index) reached 5 (Fig. 6) and it was at this stage of regrowth that the maximum daily rate of herbage accumulation was reached (Fig. 7).

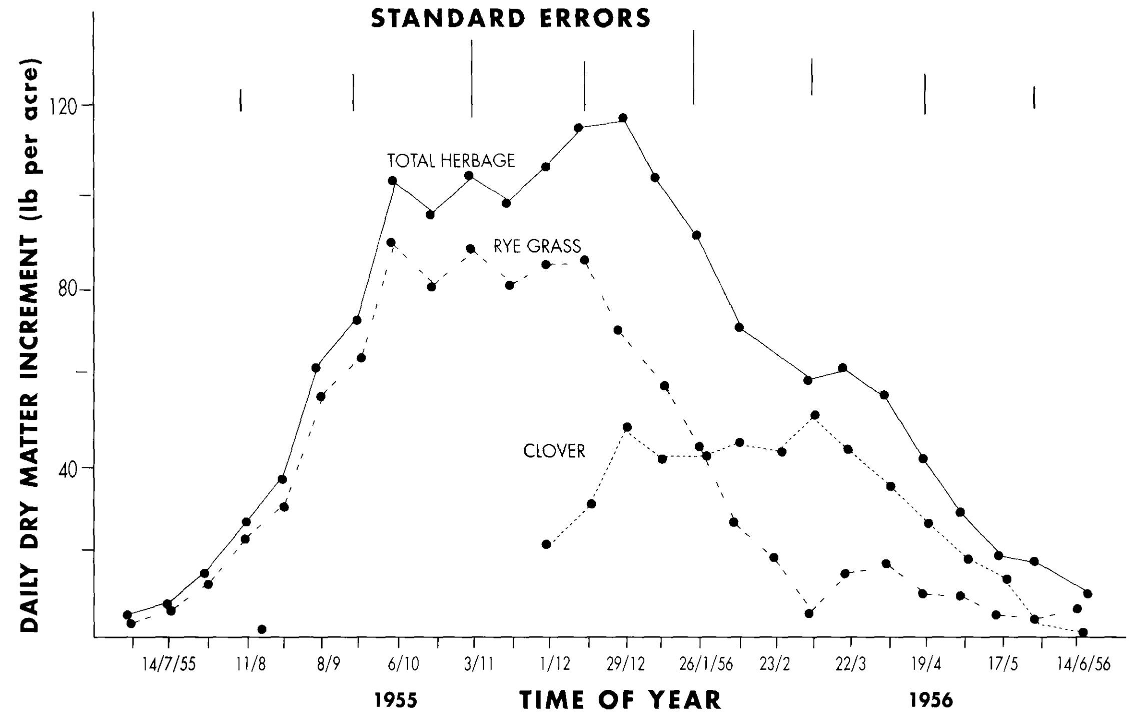

Figure 5.- Increments of total herbage, ryegrass and clover dry matter for the third and fourth weeks of pasture regrowth from a time series of defoliations in the course of a year at Palmerston North, New Zealand. Standard errors relate to total yield.

Figura 5.- Incrementos de la producción de materia seca total, del raigrás y del trébol entre las semanas tercera y cuarta del rebrote del pasto, correspondientes a una serie de fechas de aprovechamiento en el transcurso del año en Palmerston North, Nueva Zelanda. Los errores típicos corresponden a la producción total.

Differences between the cutting heights in the efficiency of leaf to provide herbage dry matter increases were demonstrated, but the more important effect was the period taken by the cutting heights to reach 95% light interception. This took 24 and 16 days for cutting to 2.5 and 7.5 cm respectively, whereas the leaf left after cutting to 12.5 cm was sufficient to intercept most of the light (Fig. 8). Consequently drymatter increments were highest for the most leniently defoliated treatment (Fig. 9). This finding supported the conclusion that, for maximum production of herbage, the amount of leaf left after defoliation by grazing or mowing should be sufficient to ensure complete interception of light. Grazing using the 95% light interception criterion became a maxim in Brougham's extension of his findings to the management of pastures by grasslands farmers. However, as will be seen from his later studies, this criterion was to be qualified according to season and other factors.

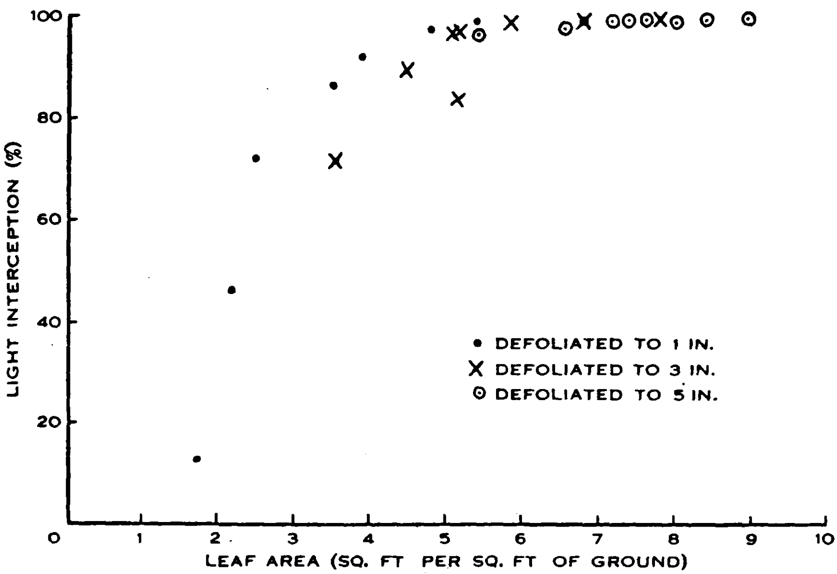

Figure 6.- The relationship between the percentage interception of incident light by the leaf area of ryegrass-clover pasture defoliated to three heights (Brougham, 1956b).

Figura 6.- Relación entre el porcentaje de interceptación de la luz incidente y la superficie foliar de un pasto de raigrás-trébol cortado a tres alturas (Brougham, 1956b).

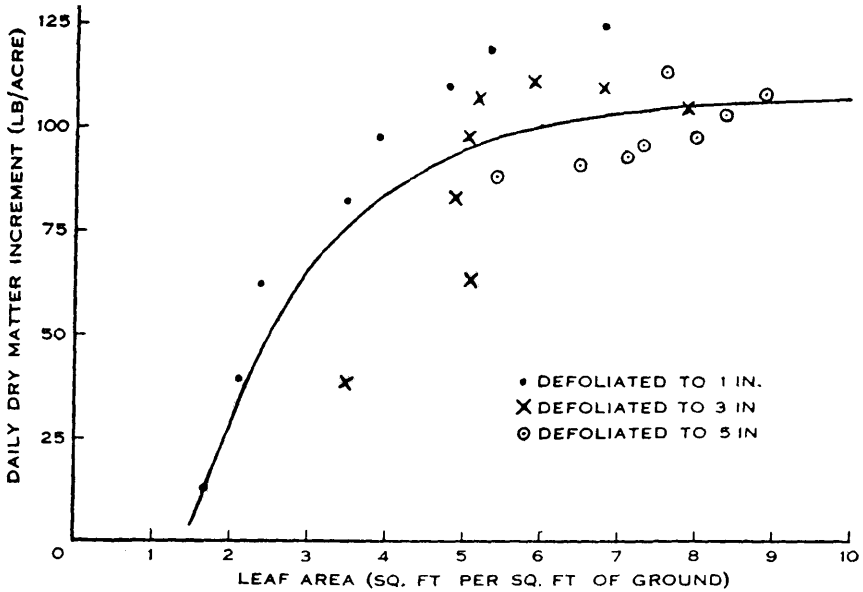

Figure 7.- The relationship between herbage dry matter increment and the leaf area of ryegrass-clover pasture defoliated to three heights (Brougham 1956b).

Figura 7.- Relación entre el incremento de la producción de materia seca y la superficie foliar de un pasto de raigrás-trébol cortado a tres alturas (Brougham, 1956b).

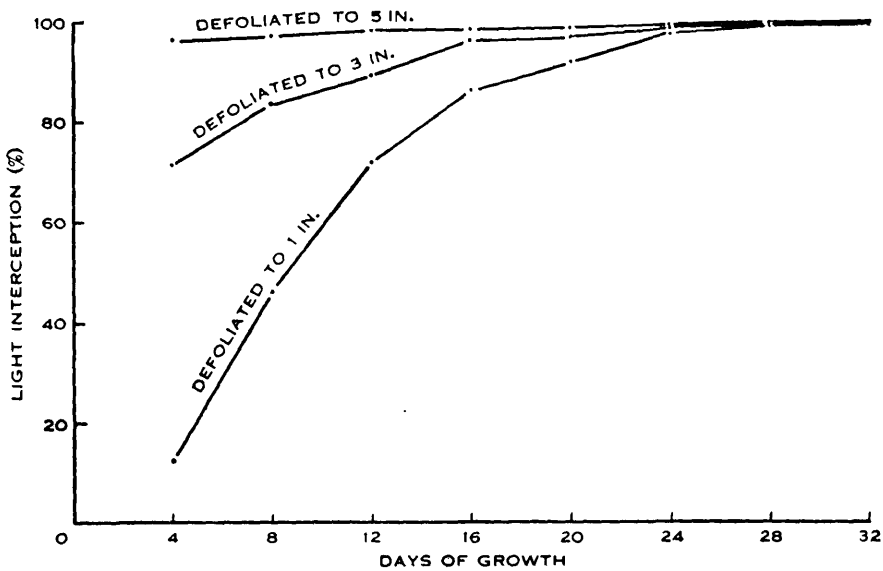

Figure 8.- Changes of percentage interception of incident light in the course of the growth of ryegrass-clover pasture defoliated to three heights (Brougham, 1956b).

Figura 8.- Cambios del porcentaje de interceptación de la luz incidente en el transcurso del rebrote de un pasto de raigrás-trébol cortado a tres alturas (Brougham, 1956b).

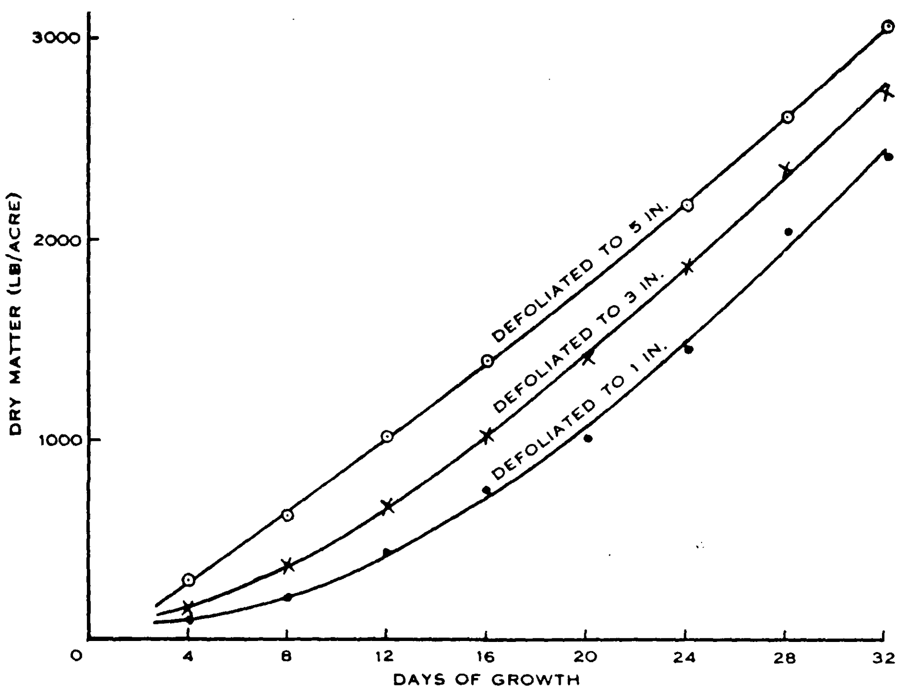

Figure 9.- Growth curves of ryegrass-clover pasture defoliated to three heights (Brougham, 1956b).

Figura 9.- Curvas de crecimiento de un pasto de raigrás-trébol cortado a tres alturas (Brougham, 1956b).

In extending light interception studies to pastures composed of different species Brougham (1958a) found that in midsummer at midday the leaf area indices at which 95% of the incident light was intercepted differed considerably. These leaf area indices were: short-rotation ryegrass, 7.1; perennial ryegrass (*Lolium perenne*) 7.1; timothy (*Phleum pratense*) 6.5; white clover 3.5; and short-rotation ryegrass and white clover mixture 4.5 (Fig. 10). Changes in the leaf area index intercepting 95% of incident light in the course of a day and during different seasons were also measured. The different light intercepting characteristics of the grasses and white clover were explained by their different leaf arrangements. The horizontal leaves of white clover directly intercept more light than the long slender, largely erect leaves of the grasses that allow light to penetrate and to be reflected further in to the pasture canopy. Brougham concluded that in order to most effectively utilize available light to maximize pasture growth herbage, height at commencement of grazing and the amount left after grazing would be appreciably lower in winter than in summer. Keeping pasture shorter during winter would also have the advantage of lowering pasture losses by reducing plant tissue decomposition. White clover would produce at its maximum rate under closer grazing than grass, and for grass-clover mixtures the recommendation was that the grazing height should be determined by reference to the light-intercepting characteristic of the dominant species component.

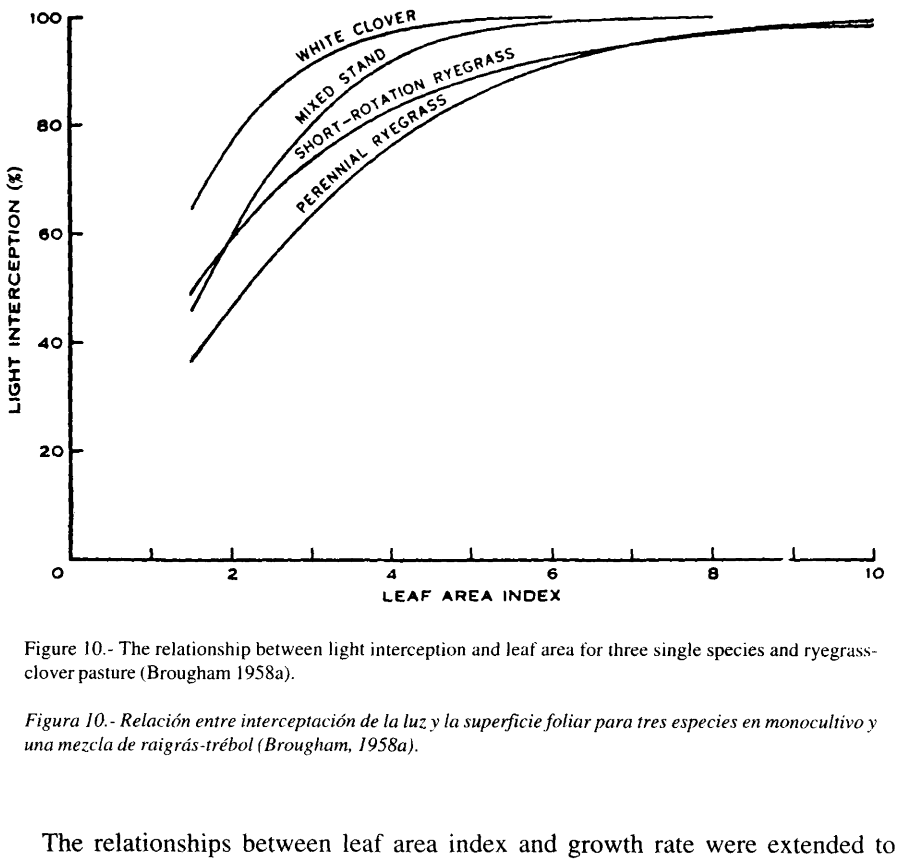

Figure 10.- The relationship between light interception and leaf area for three single species and ryegrass-clover pasture (Brougham 1958a).

Figura 10.- Relación entre interceptación de la luz y la superficie foliar para tres especies en monocultivo y una mezcla de raigrás-trébol (Brougham, 1958a).

The relationships between leaf area index and growth rate were extended to a consideration of how these related to the chlorophyll content of the leaf area intercepting 95% of incident light (Brougham, 1960c). A highly significant correlation was found between the maximum growth rates of the eight species studied and their chlorophyll content. However growth rate proportional to the amount of chlorophyll was found to be higher for red and white clover, kale and maize which have horizontal or distinctly flagging leaves compared to the erect leaved perennial and short-rotation ryegrasses. This differences was attributed to either differences in the efficiency or activity of chlorophyll between the two groups of species or to greater partitioning of drymatter to the underground organs of the erect-leaved grasses.

Anslow (1965) concluded from results of an experiment conducted at the Grassland Research Institute, Hurley, England, that there was no significant relationship between leaf area index, light interception and growth rate of a perennial ryegrass sward in mid-summer. He emphasised his conclusion further by stating that higher growth rates would not be obtained by paying attention to the relationship between light interception and leaf area index. Brougham & Glenday (1967) reexamined Anslow's data to show the sigmoid form of the regrowth curves and a well defined linear relationship between leaf area index and yield.

This was the beginning of long running and still unresolved differences of opinion about the advantages of rotational grazing systems particularly as such systems relate to manipulation of the light intercepting characteristics of pasture. Putting aside the effects of grazing animals on pasture, I venture that much of the opinion that came out of the British Isles which was contrary to Brougham's emphasis about the importance of leaf area index and light interception and pasture growth did not take in to account key differences between New Zealand and British grassland systems. In New Zealand year-round grazing is the universal practice whereas in much of the British Isles stock are removed from pasture for a considerable period during the cold months of the year. This in itself introduces a significant element of rotational grazing into British grazing systems. In New Zealand, management of grazing over autumn and winter has to take into account the continuity of supply of adequate levels of herbage for livestock requirements, at the same time ensuring that botanical composition and photosynthetic capacity of the sward gives the most favourable growth response to seasonal environmental conditions.

Climatic differences also mean that the period of reproductive growth of ryegrasses is more concentrated and intense in the British Isles than in New Zealand. Consequently changes in biomass partitioning associated with flowering have a more dominating influence on the relationships between leaf area index and light interception than is the case in the lower latitudes where New Zealand lies. Leafe *et al.* (1974) gave a good account of the interacting factors that regulate pasture yields in spring in England - increasing levels of radiation in spring allows levels of optimum leaf area index and ceiling yield to advance progressively; partitioning of more assimilates to shoots than to roots increases harvest index; and stem extension promoted by reproductive growth results in new leaves emerging and developing higher in the sward where there is more light. Also, the climatic restriction of pasture production in the British Isles does not allow the clear separation of seasonal dominance of pasture species characteristic of New Zealand pastures as clearly shown in the study of season and weather on the growth of ryegrass-clover pasture (Brougham, 1959a; Fig. 5). As shown by the progression of ideas tested in his experimental work, Brougham included strategic grazing both to bring about seasonal changes of species dominance and to condition the photosynthetic efficiency of swards in the grazing systems he promoted.

Brougham's ongoing interest in more detailed studies of light relations in pastures is indicated by his involvement in a study of the spectral analysis of radiation transmitted and reflected by 16 contrasting vegetation types (Scott *et al.*, 1968). During my involvement with him as technical assistant in his chlorophyll work he discussed the possibility of undertaking a study in a locality with distinctly different levels of incident radiation. Fiji was mentioned as a very suitable locality but we did not manage to get there. However his career path was to take him away from more detailed fundamental studies. Instead, as much as his administrative responsibilities allowed, he concentrated more on demonstrating the practical applications of his fundamental understanding of light relations in pastures and how this could be manipulated to optimise pasture production. He continued to be very supportive of those engaged in more fundamental aspects of pasture research, mindful as a result of his own experience of the linkages between research at this level and progress in applied grassland farming technology.

EFFECTS OF GRAZING FREQUENCY AND INTENSITY

From the basis of understanding gained from his cutting experiment studies of factors regulating pasture growth rate, Brougham (1959b) initiated experiments investigating the effects of frequency and intensity of grazing with sheep on the productivity of short-rotation ryegrass and clover pasture. With reference to the growth curves of this pasture type (Brougham, 1955, 1956b) four grazing treatments were applied. These were grazing from: 8-10 to 2.5 cm (frequent-hard); 15-23 to 2.5 cm (infrequent-hard); 18-20 to 8-10 cm (frequent-lax); and 23-30 to 8-10 cm (infrequent-lax). The last two treatments aimed to leave a considerable amount of green tissue after grazing, whereas for the first two most of the photosynthetic tissue was removed with a contrast of different lengths of spelling between grazing. These treatments were continued for two years and the yield of herbage removed by grazing, botanical composition, ryegrass tiller numbers and soil-moisture levels measured. It was found that annual herbage production was highest under infrequent grazing, was also high under frequent-lax grazing, but was reduced by hard grazing. These treatments had distinctive effects on yields of the species with short-rotation ryegrass favoured by infrequent grazing, red clover by lax grazing and white clover by frequent grazing. Seasonal effects on the impact of the grazing treatments were observed with the performance of short-rotation ryegrass being especially impaired by hard grazing in late summer and autumn, whereas hard grazing provided more yield in winter. This winter effect was attributed to the lower level of foliage left after grazing required to intercept incident light, and the reduction of herbage losses from decomposition. Longer term effects of hard grazing on the persistency of short-rotation ryegrass were also observed. The final concluding remark of the paper, that there was a need for wide-scale field experiments covering both pasture and animal productivity reactions to differential frequencies and intensities of grazing, points to the direction of his later experimental and administrative work.

Effects of frequent-hard grazing in different seasons on the productivity and botanical composition of a short-rotation ryegrass, cocksfoot (*Dactylis glomerata*) red and white clover were studied in an experiment (Brougham, 1960a) that overlapped the experiment just described. Six grazing treatments were applied for a year: frequent-hard all year; frequent-lax all year; and frequent-lax with periods of hard grazing in winter, spring, summer or autumn. This was followed by six months frequent-lax grazing of all treatments. Two key facets of grazing management were highlighted by this study and these were the subjects of subsequent detailed studies. First was the susceptibility of all the species except white clover to hard grazing in summer that caused a longer term reduction of pasture production. Secondly was the usefulness of hard grazing in autumn to bring a switch from the summer dominance of the clovers and cocksfoot to ryegrass with its capacity for higher winter growth rates.

DETAILED STUDIES OF WHITE CLOVER SWARDS

In spring 1957 Brougham embarked on a series of intensive studies on the leaf growth and development of white clover swards. This involved the marking, measurement of development, and classification of individual clover leaves from the bud stage to when they died. The first experiment (Brougham, 1958b) measured leaf development of a pure white clover stand for two months from when it was cut to 1 to 2 cm in mid spring. The leaf area index reached a ceiling of 5.5 20 days from cutting and remained at about this level thereafter. Of this leaf 3-3.5 units were open, actively photo-synthesising leaves, 0.5 units were buds, 0.5 units were small axillary leaves, and 1-1.5 units were senescent. Resulting from the changing light environment of the developing clover canopy, laminae of leaves initiated after ceiling leaf area index was attained were twice the size of first formed leaves, and petiole dimensions were 2.5 and 4 times the length and weight respectively. The observations on clover leaf death that reached a significant level 20 to 30 days after defoliation were related to the turnover of symbiotically fixed nitrogen. However, more emphasis was placed on reducing the loss of herbage dry matter by avoiding long spelling of clover dominant pasture.

These observations were extended to follow the changes in undefoliated stands of white clover during a complete year (Brougham, 1962). The amount of leaf present in the stands and clover leaf dimensions (Fig. 11) changed markedly with season being at a minimum in winter and highest in late spring. These changes were determined by an equilibrium between the light environment and leaf growth that ensured a high percentage of incident light was intercepted by actively photosynthesizing leaves. Maintenance of this equilibrium involved changes in the rates of initiation and senescence of leaves, the number of leaves per unit area, and leaf dimensions. The discussion about these changes endeavoured to separate the various controlling environmental factors. Variation in temperature levels and moisture supply set the limits within which changes in the intensity, duration and quality of light were effective. The study emphasised the large-scale alterations of processes involved in leaf development brought about by defoliation of the

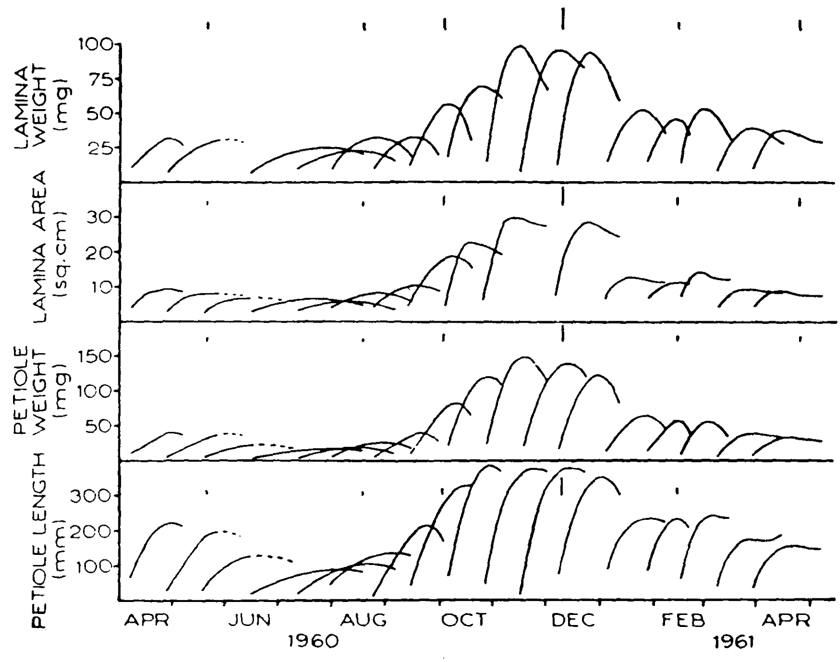

Figure 11.- Changes of the dimensions of a time series of marked leaves in an undefoliated stand of white clover in the course of a year (Brougham, 1962). The vertical bars are two standard errors in length.

Figura 11.- Cambios de las dimensiones de una serie temporal de hojas de trébol blanco, marcadas en un pasto no defoliado, en el transcurso de un año (Brougham, 1962). La longitud de las barras verticales es igual al doble de los errores típicos.

clover leaf canopy, followed by a rapid readjustment of the leaf canopy to a state of equilibrium with incident light levels.

The third experiment in this series observed the effects of red clover on the leaf growth of white clover under long spelling in summer (Brougham, 1965a). Red clover resulted in marked reduction of the weight and number of white clover leaves and buds and increased leaf etiolation. The practical recommendation arising from this study was that where red clover was included in a pasture mixture for its ability to produce herbage in drier summers, management should ensure that it should not dominate white clover to the extent that the nitrogen fixing capacity of the pasture was impaired.

In connection with his detailed clover studies Ray Brougham's first major overseas involvement appears to be his attendance at the X International Botanical Congress in Edinburgh in 1964 for which he prepared a paper on factors affecting grass-legume balance in grazed pastures (Brougham, 1964). He did not deliver the paper because the previous speakers in the session in which he was involved took up the time allotted for his presentation. This experience may have influenced his strong motivation to encourage broad and active participation by those attending grassland conferences. His ambitions in this respect were apparent in the organisation and outcomes of the XVII International Grassland Congress at Palmerston North in 1993.

ADMINISTRATIVE RESPONSIBILITIES, RECRUITS AND CO-WORKERS

In 1960 Ray Brougham became head of the Pasture Ecology Group of Grasslands Division when Dr B. R. Watkin took up a position at the University of New England, Armidale, Australia. Later Bram Watkin was to return to Massey University as Professor of Agronomy, and their long association was very important in the strong links that developed between the Agronomy Department and Grasslands Division.

This appointment to an administrative position was at a time when DSIR was expanding its activities and actively recruiting and supporting university science students in their ongoing studies, many to doctoral degrees. My involvement with Grasslands Division and grassland research began at this time. By then Ray Brougham was confident in his ability as a research worker, had an international reputation in grassland science and had developed a network of contacts with grassland farmers and farm advisors. He readily interacted socially with the young science recruits and involved them in the discussion and testing through experimentation of his evolving ideas. Amongst these people he found coauthors, and for a greater number he had an important influence on the lines of research they followed.

CHARACTERISTICS OF THE BASE OF PASTURE, SENESCENCE AND DECOMPOSITION

Brougham's studies of the production and senescence of tissue in undefoliated white clover stands were extended to obtain similar information for Italian ryegrass (*Lolium multiflorum*) in a collaborative study with Tony Hunt (Hunt & Brougham, 1966). Tiller numbers declined progressively and the rate of leaf appearance and mature leaf size increased in a undefoliated stand of Italian ryegrass over a period of six months from winter to summer. The average number of mature leaves per tiller remained relatively constant during the winter months but increased in spring. Total yield, particularly stem tissue, increased progressively from early spring. This study emphasised the loss of dry matter in undefoliated stands of ryegrass. It was the precursor to a study of structural changes of stubble developed under the frequent-lax grazing that Brougham recommended for ryegrass based pastures in summer (Hunt & Brougham, 1967). This study followed the growth in late summer of a perennial ryegrass sward cut at seven day intervals to a height that left sufficient herbage to intercept 90 to 95% of incident light at noon. After initial increases following the first cuttings, tiller numbers and the amount of green leaf tissue declined over the 49 days of the study. Yields of sheath and dead matter increased progressively during the same period resulting in a sward of relatively low photosynthetic capacity. This emphasised the need for hard "clean up" grazing in autumn following the recommended frequent but lax grazing of pasture during summer. Warren Hunt followed these studies by focusing on leaf death and decomposition in pasture, and acknowledged the guidance and encouragement Ray Brougham provided in support of his work (Hunt, 1970, 1971).

RYEGRASS PERSISTENCY AND GENOTYPIC CHANGES

Using the short-rotation based pastures from his study of the effects of frequency and intensity of grazing (Brougham, 1959b), Brougham collaborated with Glenday and Grasslands Division plant breeder Steve Fejer in determining the genetic structure of the resulting ryegrass populations. As a hybrid, short-rotation ryegrass had a wide genotypic structure with the potential to be changed by selection induced by different grazing systems (Brougham *et al.*, 1960). They found that there had been selection towards perennial ryegrass types under frequent-hard grazing and towards Italian ryegrass types with infrequent-lax grazing. This study showed the usefulness of the simply inherited characters of root fluorescence under ultra-violet light and seed awning as markers in genecological studies of ryegrass (Fig. 12).

The technique was applied to a mixture of "Grasslands Ruanui" ryegrass and "Grasslands Manawa" short-rotation ryegrass to start from an even wider genetic base than that provided by "Manawa" alone (Brougham & Harris, 1967). Within six months from sowing lax grazing brought about a marked shift towards plants with "Manawa"-like characteristics and continuous-close grazing caused a shift to "Ruanui" like plants (Fig. 12). After this initial rapid change further shifts in the genotypic structure of the ryegrass populations were more gradual until the observations were concluded three years from sowing. More detailed study of the genotypes of the surviving populations were made in the sixth year from sowing (Harris & Brougham, 1970). By then 96% of the ryegrass forming the lax-grazed pasture were "Manawa-like" indicating that this cultivar was persistent under this management. By contrast only 12% of the ryegrass remaining with continuous grazing were "Manawa-like", and these genotypes had vegetative characteristics intermediate between those of "Ruanui" and "Manawa". These results were discussed in respect to the formulation of seeds mixtures suitable for different grazing management systems, and the indicated potential for selection of genotypes with elements of *L. multiflorum* characteristics able to persist under frequent-hard grazing. We extended this line of study to following changes in the genotypic structure of ryegrass populations sown on hill, terrace and sand dune country in the Manawatu. Results from the hill pasture are presented in Harris (1973).

Related to these studies of changes in the genotypic structure of ryegrass populations was a specific study of factors influencing the persistency of short-rotation ryegrass (Brougham, 1961b). In particular this emphasised the higher elevation of the growing points of short-rotation ryegrass compared to those of perennial ryegrass, especially during the flowering period. Consequently short-rotation ryegrass was more susceptible to hard grazing during this period, and this contributed to its poor persistency under hard summer grazing (Fig. 13).

BOTANICAL COMPOSITION AND BROWNTOP

From when his experimental work started, beginning with the pasture establishment studies, Brougham made observations on the changes of botanical composition caused by the cutting and grazing treatments applied. This work was with young pastures in which the sown grasses and legumes remained as the dominant species under the variations of rotational defoliation applied. It was not until the studies of changes of genotypic structure of ryegrass populations that a continuously grazed treatment was studied. The structure of

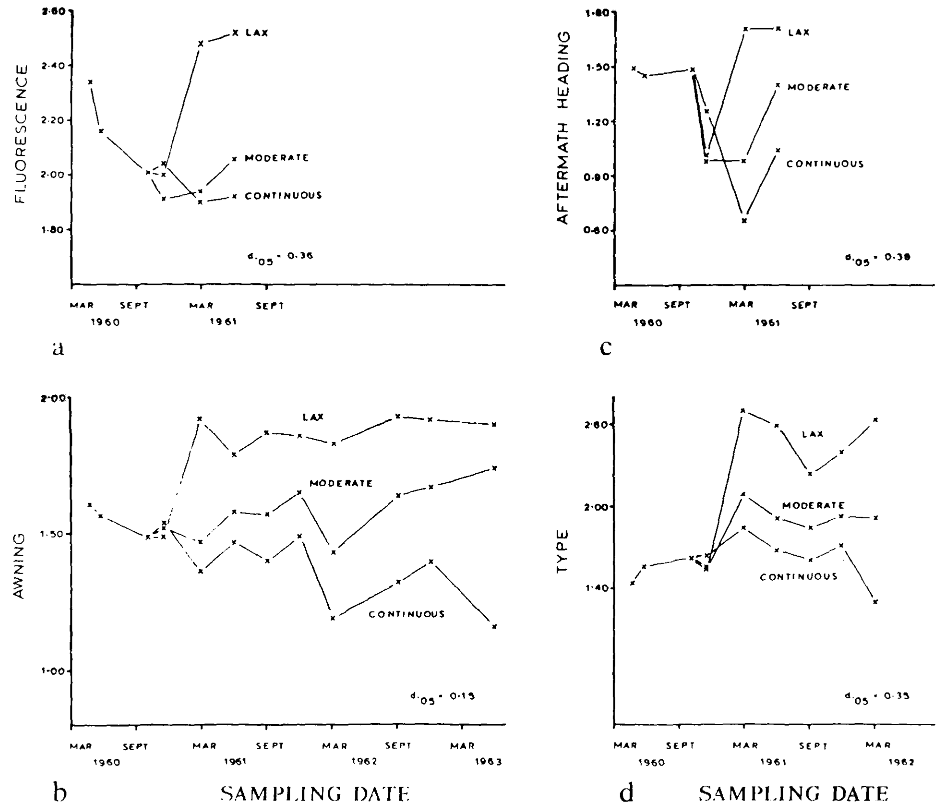

Figure 12.- Changes in the characteristics of surviving ryegrass plants in a mixed sowing of 'Grasslands Ruanui' and 'Grasslands Manawa' ryegrasses under three grazing treatments (Brougham & Harris, 1967).

Figura 12.- Cambios en las características de las plantas supervivientes de raigrás en una mezcla de raigrás inglés 'Grasslands Ruanui' y raigrás híbrido 'Grasslands Manawa' bajo tres tratamientos de pastoreo (Brougham & Harris, 1967).

the botanical composition of this treatment compared to rotationally grazed pasture was the subject of a study (Harris & Brougham, 1968) that linked in to wider consideration of pasture composition and management systems beyond the fertile lowland soils of the Manawatu. Continuous-close grazing had brought about the marked ingress of browntop (*Agrostis capillaris*), *Poa* species and a number of prostrate dicotyledonous weeds,

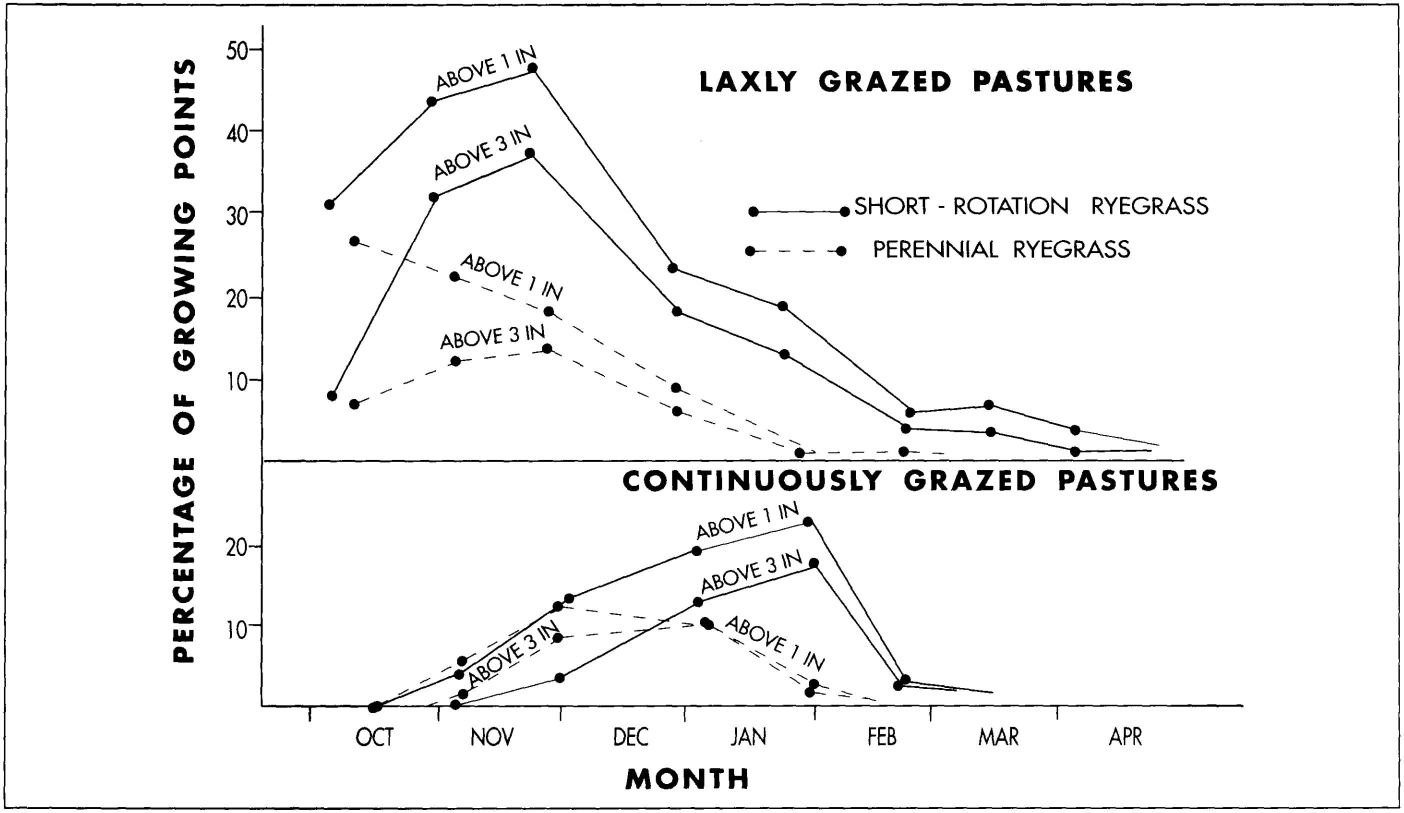

Figure 13.- Percentages of `**Grasslands Ruanui**' and `Grasslands Manawa' growing points above 1 in. (2.5 cm) and 3 in. (7,5 cm) in laxly and close and continuously grazed pasture (Brougham, 1961b).

*Figura 13.- Porcentaje del **número de puntos** de crecimiento de raigrás inglés `Grasslands Ruanui' y raigrás híbrido `Grasslands Manawa' por encima de 1 pulgada (2.5 cm) y 3 pulgadas (7,5 cm) en pastoreo **laxo e intenso** y contínuo (Brougham, 1961b).*

whereas the rotationally grazed swards remained ryegrass-clover dominant. In the continuously grazed treatment browntop showed a negative association with ryegrass, while ryegrass, *Poa* and white clover were positively associated. These species associations were characteristic of the wet hill country of the North Island where after the sowing of ryegrass based seeds mixtures pastures usually developed rapidly towards browntop dominance (Harris, 1973). The differences of botanical composition between rotationally and continuously grazed pasture provided the stimulus for my experimental studies of the competitive interactions between ryegrasses, browntop and white clover (Harris & Thomas, 1970).

The frequency of occurrence of browntop in different topographical and soil type areas of the Manawatu was investigated in surveys undertaken in 1967 and 1968 (Brougham *et al.*, 1974). It was found that the frequency of occurrence of browntop in hill country was more than 80%, less than 40% on terrace country and less than 20% on flat country. Browntop content was generally less in dairy than in sheep pastures, and differences of browntop content on hill country farms were noted according to the management systems used. This study was influential in the focus on evaluating rotational grazing systems in the research programme undertaken on the Ballantrae moist hill country regional station in the Manawatu acquired by Grasslands Division in 1966 to replace the hill country site at Te Awa.

ANIMAL FACTORS

Although Ray Brougham was primarily a plant scientist and particularly a plant ecologist, the animal factor was always part of the research he undertook, and consideration of this factor became stronger as his work progressed. One of his earliest duties at Grasslands Division was the unpleasant task of collecting and returning urine and dung from sheep in Sears'(1953a, b, c) pasture growth and soil fertility experiments. Certainly this experience would have contributed to his concern and knowledge about the roles of grazing animals and legumes in nitrogen cycling, and he supported further study of these roles while he was Director of Grasslands Division.

In the period up to the mid-1960s there were practical limitations to the scope of grazing studies that could be undertaken by Grasslands Division, particularly on the limited area of lowland fertile soil at Palmerston North. There was a tacit agreement that DSIR should focus its effort on more fundamental and particularly plant related grassland research, leaving the animal and more applied aspects to researchers in the Department of Agriculture. Even so, this tacit agreement did not deter Dr C. P. McMeekan, Head of the

Department of Agriculture Research Station at Ruakura, Hamilton, from making scathing comment about the scale and practical relevance to grassland animal production of research undertaken by Grasslands Division.

Brougham's early grazing experiments were conducted on small areas and used sheep as the grazing animal on an on-off basis, measuring treatment responses by herbage production and not by animal production. However he did work in collaboration with animal scientists at Massey Agricultural College and with DSIR Plant Chemistry Division scientists involved with detailed aspects of animal physiology. Through these involvements he was well aware of relationships between pasture quantity and quality and livestock production and health (Flux *et al.*, 1960; Rae *et al.*, 1963, 1964). Others in Grasslands Division picked up and developed further Brougham's collaborative involvements in relationships between pasture quality and animal performance and health (Lancashire & Keogh, 1966a, b). However when Grasslands Division purchased 125 ha at Aorangi on the Kairanga Plains, Manawatu in 1967, he grasped the opportunity to test his ideas by experiments measuring herbage and livestock production and investigating interactions between plant and animal in larger-scale, self-contained grazing systems. Aorangi became the focus of Brougham's last major phase of experimental work. He remained directly involved in the management and measurement of a series of pasture and livestock production experiments at the site right through his period as Director of Grasslands Division from 1971 to after he retired in 1985.

In respect to the opportunity provided by Aorangi, the concluding remarks made by Ray Brougham in the plenary paper he presented at the XI International Grasslands Congress at Surfers Paradise, Australia (Brougham, 1970b) is interesting. He called for the direction of more effort to the investigation of the many interacting factors in the soil-plant-animal complex of grassland farming with emphasis on ecological studies where the whole rather than part of the complex is studied. While acknowledging the place of computer simulation studies he expressed the opinion that these should not be undertaken at the expense of studies of the whole. He stated his view that much better use would be made of research data if research workers translated basic results into practise by sensibly-devised and practically-orientated experimentation. This was the nature of the research at Aorangi.

AORANGI AND DAIRY BEEF

Unfortunately, a significant part of the results from the Aorangi farmlet studies have not been fully analyzed or formally published in scientific journals. However the studies served a valuable role for almost two decades as direct and practical demonstrations to grassland farmers, farm advisors, and the international community of grassland scientists, of the principles of grazing management practice derived by Ray Brougham. He drew on results from these experiments in his frequent role as a speaker at grassland science and farmers meetings, and together with papers published with and by co-workers involved at Aorangi, and in information presented in the Grassland Division Research Reports from 1978 to 1984, the main findings of these experiments are available.

Measurements for the first of the farmlet studies began in 1969 and involved six small farmlets of 1.62 ha stocked with dairy bulls that were predominantly Friesian. This layout allowed three replicates comparing two farming systems (Brougham *et al.*, 1975). The pasture was 20 years-old and predominantly perennial ryegrass and white clover with a significant browntop component. The systems compared were self-contained all-year-round rotational grazing with and without a feeding or loafing platform. For the farmlets with platforms, bulls were held on these during wet periods in winter and spring to reduce treading damage and feed wastage by trampling. Hay was conserved in each farmlet and fed back in the farmlet in which it was conserved.

It is interesting that Brougham chose loafing platforms as the treatment comparison as treading damage was the particular specialist interest of his contemporary at Grasslands Division, Don Edmond (Brown & Evans, 1973), who died at an early age in 1971. Edmond had demonstrated significant reduction of herbage yield and changes of botanical composition by treading in small plot experiments, and there was a period in the 1960s when loafing pads were constructed on many New Zealand dairy farms. It is also appropriate to record the involvement of Don Johnston, Consulting Officer, New Zealand Dairy Board, with this farmlet study. I particularly recall the frequent consultation between Ray Brougham and Don Johnston driven by their strong motivation to improve the productivity and profitability of grassland farming. Defining potential levels of maximum grassland production, and considering the management options to reach these levels, were probably the strongest element in Brougham's public speaking appearances in the late 1960s and throughout the 1970s. The Aorangi experiment became a focus of Brougham's and Johnston's joint effort to practically demonstrate maximum animal production levels from pasture.

The effect of using a platform was small and it was concluded that feeding or loafing platforms were of limited value (Brougham *et al.*, 1975). It was also shown that there was little or no value in the conservation and feeding out of hay. The better option was to conserve herbage grown during peak periods of growth "*in situ*" to be held in reserve to feed to the bulls in periods of low pasture growth. The most significant outcome of this farmlet experiment was that it demonstrated that high yields of dairy beef could be obtained by the system of grazing management used. The statement of animal production "greater than 1000 kg hot-carcass weight per hectare" became a common phrase in Brougham's presentation of his results from the Aorangi farmlet studies. This carcase yield level was indicated to be five times higher than the average yields produced from intensive North Island fattening units at the time of the study.

Brougham considered that the basis of this high level of animal production was the system of rotational grazing used. Consequently, description of the rotational grazing management system is of more interest than the platform comparison. In mid-spring (November) three month old weaner bull calves were bought on to the farmlets and were maintained on these at a stocking rate of 7.4 bulls/ha to 16 to 20 months of age when they were killed. Feed shortages, usually caused by the onset of summer dry weather, determined killing time. Consequently, for a period of 1-4 months in late spring and summer there was overlap of older bulls and weaner calves. During this overlap period the calves were grazed as leaders and the bulls as followers.

The key pasture management process was the implementation of daily rationing of herbage available to the bulls with the onset of autumn rains. This was achieved by block rotational grazing involving stock control with portable electric fences, and allowed the farmlets to get in to long rotations. This had the joint effect of increasing pasture growth in response to autumn rain and carrying herbage forward into winter and early spring during which times current herbage growth was less than that required to maintain the growth of the bulls. Over the four years of the experiment reported, the first autumn rotation, which began around 1 April, provided a spell between grazing of 62 to 73 days, the second from 46 to 54 days, and the third which carried the farmlets into the period of maximum spring growth, 31 to 43 days. Thereafter through spring and summer the rotation varied around 32-days. As a consequence the paddocks in each farmlet were grazed 10 to 11 times each year. In respect to his earlier grazing experiments it is relevant to note that the implementation of block grazing in autumn, implemented most directly for feed rationing and "*in situ*" herbage conservation, also served as an "autumn clean up grazing" to condition the pasture for winter and spring growth (Brougham, 1960). However the need for a long rotation over winter to carry feed forward compromised the potential benefit of reducing herbage loss by decomposition by more frequent defoliations during this season (Brougham, 1956a).

The important effects of the intensity of summer grazing identified in Brougham's earlier studies (Brougham, 1960a, 1961b) were the focus of a farmlet study that began in 1973 and continued to 1977. The treatment contrast was between overgrazing for a month in summer compared to management to avoid overgrazing. The brief reporting on the animal production outcome of this experiment was that there were appreciable differences in bull performance in autumn and early winter after summer overgrazing, but for the full year the treatment effect was small (Grassland Division, 1978a). This study was used to compare techniques for measurement of the feed intake of the bulls (Clark & Brougham, 1979) and the patterns of compensatory growth of the bulls that evened out their liveweights on the treatments are shown. The suggestion arising from this study that animal production from the system could be obtained by improving pasture digestibility in summer by inclusion of improved summer-active pasture varieties was investigated in the next farmlet study.

Attainment of dairy beef production in the first farmlet study many times greater than that prevalent in current farming practice on old pasture with a high content of browntop posed the question as to whether inclusion of herbage cultivars selected by Grassland Division could increase productivity further. Comparatively few experiments have endeavoured to measure the improvements of animal production by the use of selected cultivars, and the responses in many of these experiments have been small or inconclusive. As breeding and selection of pasture cultivars was a major function of Grasslands Division, Brougham as Director of the Division saw the need to demonstrate the contributions new cultivars could make to animal production under appropriate management. In 1977 two farmlets with the "old" permanent pasture were compared with four farmlets sown with a "new" pasture which was a mixture of `Grasslands Nui' perennial ryegrass, G.4708 hybrid ryegrass, `Grasslands Pawera' tetraploid red clover, and `Grasslands Pitau' white clover. These were the new generation of Grassland cultivars that had become available since the standard ryegrass-clover mixture used to establish the pastures that Brougham had experimented with 20 years previously. The stocking rate of dairy bulls and the system of rotational grazing management was similar to that of the previous farmlet studies.

Results from this experiment were briefly presented at several conferences, most notably in Brougham's keynote address to the XIV International Grasslands Congress at Lexington, Kentucky, U.S.A. in 1981 (Brougham, 1983).

TABLA 1

Net hot carcass meat yields (kg/ha) from "old" and "new" pasture.

Carne canal (kg/ha) producida en pastos "viejos" y "nuevos".

Year	Old pasture	New pasture	Difference(%)
1977/78	908	1052	146 (16)
1978/79	844	938	94 (11)

In reviewing this result I consider it appropriate to point to some of the issues it raises. Most obvious is the need to assess whether the gain of meat production offset the cost of establishing the new pasture. There remains the untested question of whether use of the first generation of Grasslands cultivars that Brougham used in his pasture establishment studies would have given a different result to that obtained by using the new generation of cultivars. And there is the concern that the meat yields from the "old" pasture were less than those of the first experiment which were about the same as those from the "new" pasture.

Arising out of this farmlet experiment and the role of pasture quality in summer raised in the paper by Clark & Brougham (1979), came a particular focus on red clover as it was considered to be the main contributor to the gain shown by the "new" pasture (Brougham & Cosgrove, 1985; Cosgrove & Brougham, 1988). A separate trial was established that compared the effects on the herbage production and botanical composition of the "new" cultivar pasture of year round infrequent grazing with treatments that were grazed frequently in either winter or summer (Cosgrove & Brougham, 1985). These treatments all produced about 15 t DM/ha but it was found that frequent grazing in summer and also in winter decreased red clover yield. Particularly with frequent grazing in summer, there was a marked increase of ryegrass yield in spring and summer to compensate the reduced red clover yield. This result suggested the use of strategic summer grazing to control the red clover-ryegrass balance.

It is pertinent in two respects to comment on grazing experiments focusing on red clover that I was involved in at Aorangi when the farmlet studies were under way (Harris *et al.*, 1980; Harris & Kunelius, 1988; Kunelius *et al.*, 1982; Pineiro & Harris, 1978a, 1978b). The first comment is that while the farmlet studies were founded on Brougham's direct experience of experimentation and contact with grassland farmers and advisors, he was continually looking at contemporary experiments and incorporating findings from these in the management variables tested on the farmlets. The second is to point out the important involvement of overseas scientists in Grasslands Division work many of whom were attracted to New Zealand by Brougham's overseas contacts and international reputation. The findings of evaluation of red clover cultivars and grass mixtures in collaboration with Juan Piñeiro from Spain, and direct drilling studies with red clover in collaboration with Tapani Kunelius from Canada, were applied in the "new" pasture farmlet evaluation.

Commencing in 1979 a farmlet experiment on the "old" pasture compared treatments with no fertiliser nitrogen, 100 kg nitrogen ha/yr applied as urea in late autumn and early spring, and the same rate applied in early spring and early summer. The latter treatment gave the best response by increasing meat production by 7 to 8% annually and reduced clover content only to a small extent (Grasslands Division, 1982a). In 1981 this experiment was modified by replacing the spring nitrogen application treatment with a nitrogen plus spray irrigation treatment. Irrigation was applied to prevent the soil moisture deficit from exceeding 50 mm, and about 250 mm was applied in the period November to March (Grasslands Division, 1984). Irrigation enabled the bulls to be carried for a longer period into summer and early autumn resulting in higher carcase weights (Table 2)

TABLA 2

Pasture and dairy bull production responses to irrigation (Brougham & Cosgrove, 1985).

Respuesta al riego de la producción del pasto y de terneros del rebaño lechero (Brougham & Cosgrove, 1985).

Pasture	Herbage kg DM/ha	Dryland	Irrigated
	Annual	16970	18030
	Summer	5510	6040
	Autumn	2840	3500
Dairy bull	Live weight gain (kg/ha/yr)	2160	2340
	Mid-summer live weight gain (kg/head/day)	0.73	1.02

Following on from the "new" pastures study, in 1981 the "new" pastures were replaced with a mixture of `Grasslands Nui' perennial ryegrass, `Grasslands Pitau' white clover, and `Grasslands Pawera' red clover. This provided duplicated farmlets for three treatments: "old" pasture, "new" pasture and "new" pasture irrigated to offset summer water deficits. In 1985 a further "new" pasture combination which added `Grasslands Matua' prairie grass (*Bromus catharticus*) to the three species mixture sown in 1981 was included as a comparison. This four-species "new pasture" was grown with or without additional irrigation and fertiliser nitrogen. A summary of the herbage yields and bull liveweight gains (Table 3) from these farmlets for the period 1982 to 1897 was presented at the New Zealand Grasslands Association Conference in 1988 (Cosgrove & Brougham, 1988).

TABLA 3

Annual dairy bull live weight gains in three series of farmlet studies (Cosgrove & Brougham, 1988).

Ganancia anual de peso vivo, de terneros del rebaño lechero, en tres series de estudios en "pequeñas granjas" (Cosgrove & Brougham, 1988).

Pasture type	Treatment	Liveweight gain kg/ha/yr
"Old" ryegrass and white clover	"Old" Control	2187
	+ Irrigation	2361
"New 3-species" ryegrass, white and red clover	"Old" Control	1948
	"New 3-species "	2138
	"New 3-species" + Irrigation	2203
"New-4 species" ryegrass, prairie grass, white and red clover	"Old" Control	1829
	"New 4-species" +	1771
	Irrigation + N	1898

The most significant indications of this series of farmlet studies were the consistent increases of liveweight due to irrigation, and to the "New 3-species" pasture and a negative response from the inclusion of prairie grass. The prairie grass had a particular effect of reducing spring and summer liveweight gains and irrigation was needed to offset this.

Purists in experimental design can find much to be critical of in the Aorangi farmlet studies. Ray Brougham referred to the procedure as "seat of the pants experimentation" and gave a justification of the approach used in his plenary paper at the XIV International Grassland Congress (Brougham, 1983). To quote, "Importantly, management procedures are not fixed from year to year, although in any year the same management procedures are applied to the different treatments being compared. The management meets the needs of, and changes in, climatic, animal, pasture, and economic considerations. Using this approach, the aim is to maximise animal production/ha, and to assess differences due to treatment". He continued to say that "Investigations such as these can be the entering point for widespread dissemination of research result". There were regular meetings of a discussion group of farmers at the Aorangi farmlets. The farmers evaluated the results they saw in respect to their experience on their farms. In applying what they saw as practical they made significant contributions to the economics of dairy-beef farming in the Manawatu. I believe a comprehensive collation, analysis and interpretation of the data collected during the course of the Aorangi dairy-bull farmlet studies would be well worthwhile.

DIRECTORSHIP AND WIDENING HORIZONS

The period during which Dr Lionel Corkill was Director saw a significant advance of the skills of the Grassland Division staff and the facilities available to them for experimental work. Brougham had grasped the opportunity this progress provided by the implementation of his Aorangi farmlet studies. When the resources of Grassland Division came under his control when he was appointed Director in 1971 he had a platform to implement nationwide his vision of realising increases of animal production from New Zealand's pastures.

While he naturally related to people on a one-to one basis, often seeking their individual confidence, a significant means by which Brougham influenced the course of the entire Grasslands Divisions' research programme was through the establishment of a series of research committees. Definition of these committees was proceeded by a requirement for all staff to state the objectives, approach, and progress of all the research projects they were engaged in. While such definition of projects is a routine part of the accountability procedures applied to scientific research in New Zealand today, in 1971 for Grasslands Division scientists this was a novel requirement. Projects were then categorized according to their relevance to farming system or specialist discipline and listed in a publication for internal use in Grasslands Division. To a large extent the categorization of the projects related to the research committees that were established. While the committees predominantly involved Grasslands Division staff, personnel from other agencies, particularly the Department of Agriculture that later became the Ministry of Agriculture and Fisheries, were also included.

The first of these committees related to the wet hill country of the North Island and was set up in 1971 within a few months of Brougham becoming Director. This committee played a particular role in designing the 100 ha grazing trial at the hill country research station at Ballantrae. The experiment was established as 10 self contained farmlets that compared two levels of fertiliser input and three grazing systems (Lambert *et al.*, 1983). The grazing systems, rotational grazing with cattle or sheep and continuous grazing with sheep, were an extension of Brougham's principles of pasture management to the class of country represented at Ballantrae.

By 1974 10 research committees were functioning each of which had a specified coordinator. However, Brougham was a member of every one of these committees, many of their meetings were held in his office, and he effectively chaired most of their proceedings while simultaneously conducting other Divisional business. His "open door policy" of management was at time very frustrating for those gathered for a research committee meeting when proceedings were halted while he engaged in lengthy conversations with outside callers!

To report on the outcomes of the different research committees would almost make a history of Grasslands Division during Brougham's period as Director and much of what happened until both DSIR and Grasslands Division were disestablished in 1992. I will limit my attention to two of the committees operating in 1974, the nitrogen cycle and ecotype collection committees.

Providing a link back to Brougham's introduction to grassland research when he was involved with Sears' pasture and soil fertility studies, the nitrogen cycle committee provided the forum for the planning and implementation of studies of nitrogen fixation in pasture at nine representative sites in New Zealand. Sears' study had indicated that clovers fixed up to 650 kg N/ha, and it was widely considered that high N fixation levels were characteristic of New Zealand pastures. The outcome of this coordinated series of studies was a series of 11 papers published together in the *New Zealand Journal of Experimental Agriculture* in 1979. Brougham was co-author of two of these papers, the introduction (Ball *et al.*, 1979) and the report on the study carried out on the dairy-bull farmlets at Aorangi (Clark *et al.*, 1979). At Aorangi total annual N fixation levels averaged 225 kg/ha for the two years of the study, and like the other sites on developed lowland pasture, this was less than half that indicated by Sears. On the unimproved hill country at the Ballantrae hill country research station the average annual N fixation rate was only 34 kg/ha (Grant & Lambert, 1979).

The ecotype collection committee grew out of Brougham's experience of the process of natural selection that occurred in his studies of genotypic shifts in ryegrass populations. The early period of breeding and selection by Grasslands Division was based on the concept of the selected cultivars having genetic bases that were sufficiently wide to allow adaptation to the range of pastoral situations in New Zealand. Brougham saw the potential of more specifically adapted cultivars particularly for areas that were more difficult for pasture production. By 1973 collection of local populations of ryegrass, white clover and browntop from a wide range of sites in wet North Island hill country sites was under way (Forde & Suckling, 1980; Suckling & Forde, 1978). Later collections were made of dry hill country white clover populations (Grassland Division, 1984).

Representatives of products from these collections that are amongst the current generation of herbage cultivars available in New Zealand are 'Grasslands Tahora', a small leaved densely stoloned white clover adapted to perform on moist hill country pastures, `Prop', a small to medium-leaved and densely stoloned white clover that seeds prolifically and is adapted to summer dry environments, and `Grasslands Muster' browntop. Currently more than 50 cultivars selected and bred by Grasslands Division are available compared to the eight that were available when Brougham began his experimental work in the 1950s. Most of the developmental work that led to this large increase of cultivars was done while Brougham was Director. In addition to the three mentioned, many of the other recently released `Grassland' cultivars have characters that are tailored for performance in specific regions in New Zealand.

ACCOUNTING FOR REGIONAL DIFFERENCES OF PASTURE PRODUCTION

A recurring theme in Brougham's conference presentations in the 1970's, most comprehensively presented in a paper to the Ruakura Farmers' Conference (Brougham, 1973a), was the need to address regional differences in pasture production and livestock farming systems in New Zealand. This need was later directed to the international scene particularly when retirement from Grasslands Division freed him from the demands of administration. He worked to strengthen the facilities and staffing at Grasslands Division's regional network of stations linking the programmes of work at the separate stations to meet national objectives. His final Director's report in the Grasslands Division Research Report series (Brougham, 1984b) focused on the regional theme. The stations are recorded in this report as Kaikohe (warm temperate), Palmerston North (centre for Grassland Division), Aorangi (nucleus seed production, intensive lowland farming), Ballantrae (moist hill country), Lincoln (dryland farming, seed production), Tekapo (South Island High Country - short growing season) and Gore (cool-temperate - intensive sheep farming).

At the various regional stations Brougham contrived to bring together compatible teams to address particular research topics. For example at Lincoln the effort was focused on lowland and hill country facets of dryland farming, on intensification of forage seed production with separate emphasis on the production of grass and legume seed, and a clear identity was established for grassland research in the South Island high country. In 1982 Grasslands Division established a field station at Lake Tekapo concentrating effort on a 80 ha area whereas previously it had been spread over many site and supported with spartan facilities.

TRANSFERRING INFORMATION FROM SCIENTISTS TO GRASSLAND FARMERS

Ray Brougham's personal determination to present his research findings in ways that were of practical use to farmers and in terms that they understood was extended to the staff of Grasslands Division. He insisted that every scientific article should also have a popular summary written in terms that could be understood by university teachers, students, extension workers and farmers. These summaries were grouped according to region of application or to discipline, and were published for three periods providing a comprehensive record of the Divisions' published work from 1974 to 1982 (Grasslands Division, 1978b, 1980b, 1982b).

As well Brougham initiated a series of Research Reports in 1978 (Grasslands Division 1978a, 1980a, 1982a, 1984). In each he gave a Director's report and these provide insight on how he shaped and presented the Division in response to the changing expectations of research organisations arising from economic and political influences. In 1984, the year before he retired as Director of Grasslands Division, a radically different political ideology gained power in New Zealand that acted to demean the principles of public service that Brougham had applied to good effect. It was a good time for him to retire. He was spared the effects of externally imposed accountability processes that diverted effort from research to administration. These changes were stifling to scientific creativity and productivity. Had they been in force earlier they would have prevented him from being actively involved in research right up to his retirement. Brougham observed with concern the effects of these politically initiated changes on the work and status of Grasslands Division. Fortunately the freedoms of retirement allowed him to continue his interests in grasslands to remarkable effect.

TURF RESEARCH INSTITUTE

Like many fellow New Zealanders, Ray Brougham took a keen interest in sport. In particular those that he played well and followed throughout his life, rugby football, cricket, golf and horse racing, are sports enhanced by good quality turf.

In 1932 Sir Bruce Levy had agreed that Grasslands Division should be involved in turf research on behalf of the Greens Research Committee of the New Zealand Golf Association that had been set up in 1931. The functions of this Committee was taken over by the New Zealand Turf Institute when it was formed in 1939. For 25 years the turf research undertaken for these organisations was located at the Manawatu Golf Club. From

1957 to 1969 the turf research was transferred to the Department of Agriculture and the experimental plots were located at Milson in Palmerston North. This early period of turf research was mainly directed to management to provide a fine, hard-wearing, weed free turf of browntop (*Agrostis capillaris*) and Chewings fescue (*Festuca rubra*).

In 1969 the turf research was taken over by Grassland Division and a turf research section was established. There was a change of emphasis towards the selection and evaluation of turf cultivars and the section was well located to draw on the expertise of several DSIR Divisions who had staff located at Palmerston North. Brougham encouraged the development of the turf research programme and in the mid-1970's the national office of the New Zealand Turf Culture Institute was established on the Grassland Division site at Palmerston North.

In 1986 Brougham became President of the New Zealand Turf Culture Institute Board of Management and he continued in this role to 1990. Conferment of Life Membership in 1990 was a tribute to his contribution to the Institute during his term as President.

His most visible role in the turf industry was his contribution as Honorary Editor of the New Zealand Turf Management Journal. He began this role with the first issue of the Journal in July 1986 when it replaced the Sports Turf Review. Brougham wrote the Editorial for ten of the issues of the Journal, the first beginning with "Welcome to New Zealand Turf Management Journal" (Brougham, 1986a). The Editorials that followed were written in a relaxed and interesting style in which he commented on the affairs of the Turf Institute and the Journal, and made comment about personalities in the turf industry, sportsmen, and sport as it is played on turf in different parts of the world. For other issues he used his contacts to add variety to the Journal by arranging guest editorials. The Editorial Page of the November 1993 issue of the New Zealand Turf Management Journal is devoted to an Obituary, Raymond Wilkie Brougham, D.Sc; MBE; 1926-1993.

In the February 1990 issue Brougham introduced a new column that he titled "Something Different". He wrote eight articles for this column recounting his visits to sportsfields and contacts with turf and sports personalities throughout the world. The final paragraph of his article about "Bowls - Brazilian Style" (Brougham, 1990b) that recounts his experience of game in Porto Alegre, shows Ray Brougham's ability to meet and communicate with people through out the world - "It was a pleasant interlude, made all the more interesting and enjoyable by the friendliness of the participants, a common occurrence in most countries if one bothers to take time out to show interest in others' customs and activities".

INTERNATIONAL CONSULTANCIES

Ray Brougham's reputation as a grasslands scientist, competence in practical aspects of animal husbandry, and experience in research administration led to considerable involvements in consultancies. For world aid agencies such as the World Bank and FAO he was involved in consultancies in Argentina, Brazil, Cuba, Chile, Colombia, Ethiopia, the Himalayas, North Korea, Spain, and Uruguay. These consultancies were mostly concerned with evaluations of national pasture and animal research programmes and planning for improvements in research capability to meet national problems.

Involvement with a consortium of New Zealand commercial companies took him to China many times and he was also involved in a consultancy relating to New Zealand's scientific collaboration with Mexico. The work in China was principally in Shansi, Dushan and Gansu Provinces where he was engaged in projects concerned with pasture and land development including seed production, sheep farming, beef production, phosphate production and land development.

As well, he had direct requests from organisations in overseas countries to comment on and assess research programmes in pasture and animal production and to make recommendations for staffing, organisational structures, funding and the direction of research. These assignments also involved comment on the inter-relationships between research scientists, extension workers and farmers. In this way he became involved with the Texas A & M University and Penn State University, U.S.A.; Au Foras Toulantis, Eire; and the South African Ministry of Agriculture.

On behalf of the New Zealand Government he assessed the methods of evaluation of New Zealand bred cultivars in ten European countries. As well as the countries already listed he made contributions to meetings in Australia, Austria, France, Germany, India, Japan, the Netherlands, Poland, South Korea, and the United Kingdom.

Through these international involvements Ray Brougham met with a large number of the world's leading grassland scientists and became friends with many of them. His network of international contacts was a key part in the realisation of the vision he had for the format of the International Grasslands Congress.

THE INTERNATIONAL GRASSLANDS CONGRESSES

The Seventh International Grasslands Congress was held in Palmerston North, New Zealand, in 1956. As a 30 year old scientist having recently produced his first scientific papers this was Brougham's first major contact with the international community of grassland scientist. By today's standard of international meetings it was a small congress with 285 in attendance of whom 105 were from New Zealand. Brougham's name appears in the Proceedings with references to his early papers on pasture establishment and pasture growth, and he contributed to the discussion on the paper on "Competition Among Pasture Plants" given by Professor C. M. Donald (Donald, 1956). Donald's work was very influential in the development of Brougham's understanding of the role of light interception in pasture growth and botanical composition, an understanding that he in turn passed on to me.

Ray Brougham's intense dislike of flying kept him from greater participation in the international grasslands research for many years. However he was invited to present a plenary paper at the XI Congress at Surfers Paradise, Australia (Brougham, 1970b), and I particularly recollect his enjoyment of that occasion. I also was with him with the small number of New Zealanders who attended the XIII Congress at Leipzig in 1977. He did not present a paper at this congress and disliked the formalities and restrictions of the venue and arrangements. This was in contrast to his impressions of the alternative international grasslands meeting in 1977 at Dublin, Eire, where he was invited to present a keynote paper (Brougham, 1977a). This meeting had a far more participatory format with poster paper sessions and periods of extended discussion. It was immediately after returning from these European meetings that he experienced a serious coronary attack. He made a good recovery from this responding with sensible adjustments to his lifestyle. In no way did this health problem lessen his resolve and efforts to advance the progress of grasslands research and its application.

He often spoke to me, and undoubtably many others, about his concern that the growing size of the International Grasslands Congresses was limiting participatory discussion, that increasingly it was not attractive to extension workers and farmers, and that it was very difficult for grassland research workers from Third World countries to become involved in the proceedings. He was invited to give a plenary paper to the XIV International Congress at Lexington, Kentucky in 1981 titled "Practical livestock-forage systems: model to manager" (Brougham, 1983). In this paper he emphasised the need for hard factual data on livestock-forage systems for all regions of the world. He expressed his belief that the research workers who succeeded were those prepared to "get outside, get muck on their boots, and are not too bedeviled by the biometricians and the modellers". In his opinion the best researchers are generalists who associate with extension workers and farmers and if possible work together with them in teams. In the discussion that followed he expressed his disappointment that although he had referred to the situation of "emerging countries" no one from these countries had joined in the discussion.

It was at the Lexington Congress that Brougham became significantly active in the business side of the International Grassland Congress. At the final business meeting he proposed a resolution that the Continuing Committee of the Congress should reorganise and set up a number of "Chapters" that would be responsible for "smaller international meetings embracing the different *climatic* and *topographic* regions of the world".

At the XV Congress at Kyoto Ray Brougham was elected as the Region 5, Australia and New Zealand, representative on the International Grassland Congress Continuing Committee, 1985-1988. The XVI Congress was scheduled for Nice, France, in 1989, and it was here that it was determined that the XVII Congress would be held in New Zealand. As President of the Organising Committee for the XVII International Grassland Congress, Brougham worked with dedicated effort for the next four years to ensure that the Congress would be organised to meet the vision he had discussed for many years.

I am certain that those who were closely involved in the organisation of the XVII Congress could write interesting accounts of the trials, tribulations and triumphs of that process. From the sideline I saw and heard a little about the process, but what was clear was Ray Brougham's absolute determination that his ideas for the running of the Congress would be implemented. Recognising the costs involved in encouraging participation of people from throughout the world, and especially those from developing countries, his personal effort was in large part responsible for raising NZ$1.3 million sponsorship to meet the greater part of the NZ$1.8 million budget of the Congress.

In his Presidential Address to the XVII Congress he set down six key objectives that were used in the formulation of the Congress (Brougham, 1993). These were :

1.- For New Zealand and Queensland, Australia to share the Congress so that the venues would cover a wide range of the climates of the world.

2.- Giving equal emphasis to seeing grassland agriculture in action as to talking about and listening to others talk about it.

3.- Including smaller rural population centres as venues, preferably those with universities involved in grassland agriculture. The venues were at Palmerston North, Hamilton and Lincoln, New Zealand, and Rockhampton in Queensland.

4.- Having a presentation format that encouraged participation and structured discussion involving all attending the Congress.

5.- Involving delegates from developing countries in prominent roles in the Congress.

6.- Ensuring representation from as many countries as possible by assisting to meet costs involved in travelling to New Zealand to attend the Congress.

The Congress met all these objectives with outstanding success. In posing the question "Why we are here ?" in the Presidential address, Ray Brougham stated that perhaps the greatest challenge was to "re-establish all those involved in the custody of the world's grasslands as caring, innovative, and essential people with important and vital contributions to make for the world's good". He provided an excellent model for these attributes.

CONCLUSION

Ray Brougham was an exceptionally perceptive research scientist who was quick to identify the essence of grassland related problems, and investigated these by direct and effective means. He gave first priority to addressing practical problems in grassland farming and was exceptionally effective in transferring his findings, philosophy, and experience about grasslands to farmers.

He was a person with a far reaching and wide vision of the problems and potential of grasslands production both nationally and internationally, and in particular in his later years, did his best to assist the needs of the developing nations.

He was a man with a vision for the efficient and sustainable use of the world's grasslands, who by his own example and by the encouragement of others to share this vision, worked with dedication to bring this vision to reality.

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CONTRIBUCION DEL DR. RAYMOND WILKIE BROUGHAM A LA CIENCIA Y MANEJO DE LOS PASTOS

RESUMEN

Se revisa la contribución del Dr. Raymond Wilkie Brougham, científico neozelandés con gran prestigio internacional, a la investigación sobre pastos y a su aplicación en la práctica. Contribuyó de forma relevante al esclarecimiento de los procesos de establecimiento y crecimiento de los pastos, con énfasis especial en su relación con la superficie foliar y la interceptación de la luz, así como al conocimiento de los efectos del manejo del pastoreo sobre la composición botánica y genética de comunidades de pastos.

La aplicación de sus conocimientos sobre manejo de pastos quedó demostrada en una serie de estudios a nivel de "pequeñas granjas", que resultaron en producciones muy altas de terneros procedentes del rebaño lechero. Tuvo un gran éxito en la transferencia de sus conceptos de manejo a los ganaderos en Nueva Zelanda y, más tarde, internacionalmente. Ya retirado, hizo contribuciones importantes a la industria neozelandesa de los céspedes, para instalaciones deportivas y de recreo.

Desempeñó un importante papel administrativo en la dirección de la investigación de pastos y su aplicación, especialmente cuando fue Director de Grasslands Division, desde 1971 a 1985. Su trabajo como consultor internacional permitió que sus conceptos sobre estructuras organizativas para cubrir las necesidades nacionales y regionales de investigación y extensión se aplicasen internacionalmente. Como Presidente del XVII Congreso Internacional de Pastos, orientó su desarrollo en el sentido de estimular la participación activa de los congresistas en la presentación y discusión de los resultados de investigación de pastos y su aplicación.

Palabras clave: Establecimiento de pastos, Interceptación de la luz, Composición de los pastos, Administración de la investigación.