Improved plant management - field crops and pastures

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Summary

Potential increases in crop and pasture yields in the 1980's can be realised through improved management. For field crops the most important aspects requiring research and recommendations for commercial practice are:

- Continued investigation on and adoption of optimum planting times to ensure efficient dry matter production, water use, and grain yield, especially with direct drilling
- Studies on plant population and cultural practices to optimize dry matter production and yield with a view to increasing the range of sowing times for a range of crops
- Definition of yield increases attributable to changes in plant structure

Pasture management in the 1980's will need to balance maximum yield with the need to maintain both legumes in the sward and pasture quality. Expected increases in the costs of seed, labour and fertilizer will focus attention on improving levels of management to achieve long term plant stability and sustained animal production. Mechanical practices such as cutting and conserving feed will have little relevance in pasture and commercial property management due to excessive costs. Management decisions based on plant and animal requirements will improve pasture stability. Particular areas requiring study by agronomists and graziers are:

- defining stocking rates which maintain legumes and acceptable levels of utilization of different pastures
- testing the effects of seasonal deferment or hard grazing to benefit productive plants in the sward
- recognising periods of plant stress and indicators of pasture degeneration

Introduction

Farmers in the 1980's will continue to require skills and a high level of management to sustain or increase yields of crops and pastures. Depending on the size of operation and the farmers' aspirations, manipulation of land, labour, capital, crops and pasture should have several objectives including: (a) increasing or maximising efficiency of production in terms of profit, energy, labour or fulfilment of perceived needs, (b) conserving the basic plant and soil resources, and (c) reducing animal stress, (Moreley 1978). In addition the farmer will face fluctuating market prices, the vagaries of the climate and steadily increasing capital and labour costs. Management of crops and pastures demands more study by agronomists.

The purpose of this view is to examine evidence and ideas on improved management of crops and plants in sown pasture leading to greater yield or stability of the system. Particular attention will be paid to (i) reconciling increased productivity with economics in the use of energy and labour, (ii) identifying sources of wastage and the major limiting factors in plant production including water use, nitrogen availability and deficiencies in growth and use of pastures for animal production.

The agronomist can realise higher yields in field crops through improved plant management in a number of ways. The range of commercial cultivars in any particular crop, is usually limited to those showing wide adaptability and incorporating an acceptance level of disease and pest tolerance, or at least development patterns that allow escape from these hazards.

Pasture growth and quality varies markedly in relation to temperature, moisture, light, nutrients and defoliation. Grazing animals demand a continuous supply of protein, energy and minerals for growth but are able to adjust to feed shortages by changing grazing behaviour, recycling nutriments in the blood, mobilizing body tissues or by making compensatory gain when feed supplies are re-established. Except for lucerne, (Cameron 1976) most pastures in Australia are simply continuously grazed by animals. Management decisions have been based on animal requirements rather than on trying to alter pasture quantity and quality. The farmer can try to improve plant management in pastures by controlling movement and type of animals, stocking rate or by offering pasture with improved quality and quantity, subdivision of land or conservation of feed.

Aspects of management of field crops and pastures that require close attention are discussed below.

Time of planting

The effect of changes in sowing date on rates of phenological development has been closely studied in Australia, particularly in wheat. Prediction of flowering date can be made with acceptable accuracy (Halse and Weir 1970). Sowing rates for wheat and other winter cereals are chosen with a view to timing anthesis to occur after the date of the last frost and before the onset of late spring moisture and temperature stress.

The traditional practice of Australian wheatgrowers has been to select varieties with a long pre-anthesis growing period, and sow these early in the autumn. The unconscious aim has been to maximise dry matter production, and thereby obtain the highest possible yield. This strategy has sometimes proved successful in seasons of good rainfall. In the main, it has been inefficient because excessive evapo-transpiration has depleted soil moisture reserves to the point where significant stress in the post-anthesis period has reduced potential yield (Fischer and Kohn 1966). Recently, Fischer (1979) suggested that the evidence of the last twenty years of study on the relationships between sowing date time, moisture use and yield indicates that there is a case for using fast maturing varieties sown at later dates to reduce dry matter production to optimum levels.

This approach seems to hold promise in areas where pre-anthesis moisture supply is sufficient to allow the desired level of dry matter to be attained within the reduced time span. However, in the lower and more erratic rainfall zones of the wheatbelt, early sowing may still be required to allow optimum dry matter production despite fluctuations in available moisture. The use of late sown, early wheat varieties warrants investigation, as it seems to offer a ready method of yield increase.

In the 1980's there is every prospect of an increase in the area of the wheat crop sown by reduced tillage or even direct drilling methods. It has been noted that early growth of wheat crops established by such methods is slower (Fettel, personal communication). Whether this delay will significantly alter prediction criteria presently in use for calculating anthesis date, is a subject worthy of immediate study.

The sowing of field crops is often delayed until relatively light falls of rain occur to wet up the top 10 cm of soil. The yield losses incurred are sufficiently great to warrant investigation of the use of moisture seeking "delver" attachments to seeding equipment. These would sweep away the overlying dry soil, allowing seed to be placed in the moist underlying layers. Coupled with a moderate level of water injection into the seed band, (a technique already used on summer crops), this approach would enable optimum sowing dates to be used n a greater number of seasons.

In the 1970's there was significant research activity designed to define optimum sowing dates for the newly introduced non-gramineous winter crops; rapeseed, lupins and chickpea. The first two of these crops have now achieved a measure of grower acceptance. Studies on rapeseed in the Australian environment have been directed toward prediction of flowering date from different sowing times (Hodgson 1978) and the response to drought stress at different stages of development (Richards and Thurling 1978). Whilst a start has been made, there is a need for further definition of the effect of sowing date on optimum dry matter production of the Brassica napus and B. compestris species of rapeseed. The role of sowing date in promoting water use efficiency also requires study if higher rapeseed yields are to be achieved.

Lupins will achieve greater prominence if agronomic research can devise pathways toward more stable yields in the 1980's. This high protein grain has now achieved its rightful recognition and its role in soil nitrogen accession guarantees its future. The yield stability of present cultivars leaves room for considerable improvement, and there must be opportunities to correct this by way of improved plant management. Perry (1975) studied the effect of delayed sowing date, finding that it reduced dry matter production and yield. However, as Perry states, the reasons for this result require further study.

The non-cereal winter crops with their indeterminate flowering habit and associated plasticity reduces the potential severity of the frost constraint, which can have such devastating effects on the determinate cereals. A fruitful field of endeavour would be to quantify the degree of risk reduction, and encouraging increased adoption of this crop to increase and even out cropping incomes.

For summer crops, the opportunities for employing sowing date as a crop management tool will depend on suitable minimum soil temperatures for germination, the occurrence of temperature or moisture stress in relation to sensitive crop phenological events, and suitable climatic conditions for harvest. Contemporary studies on gramineous summer crops such as sorghum (Millington, et al. 1977), mung beams (Lawn 1979a) and soybeans (Lawn and Byth 1973) indicate that manipulation of sowing date should be carried out with a good knowledge of the relative importance of cultivar x temperature and cultivar x photoperiod interactions. Sufficient knowledge now exists to allow limited yield increases to flow from the application of these principles to the present available range of cultivars in the summer crops. The whole area of study warrants expansion as it seems to hold promise for further yield increases.

Sowing dates for perennial pastures are seldom critical factors in long-term productivity, provided sowing is accomplished when moisture and temperature favour the germination of the species. Most studies with temperate species show reliable establishment when moisture is adequate and evapotranspiration low (Campbell 1967; Dowling and Smith 1976). Yield differences in tropical pastures due to sowing date are usually lost by the second year (Jones 1975). Sowing date is therefore mot a major limitation to the wide use of pastures and does not warrant further study.

Plant population and geometry

(i) Crops

The last two decades have seen much research activity directed toward establishing optimum sowing rates for the whole range of crops in Australian agriculture. Generally, there is a significant degree of latitude around the optimum population size within which grain yield is unaffected. In wheat, reducing the plant population increases the number of grains per plant, a mechanism whereby a great deal of compensation occurs (Puckridge and Donald 1967). Similar compensation appears to be the case with other crops.

Since optimum densities for most crops are defined, and for the most part have been adopted in commercial practice, one is tempted to draw the conclusion that the opportunity for improved productivity through this avenue of management is now limited. This may not be the case. Fischer (1979) suggests that if the optimum level of dry matter at anthesis is known, changes in plant population can be a method of maintaining this optimum for different sowing dates. Fawcett (1964) has shown that for wheat under dryland conditions growing mainly on stored soil moisture, the optimum density varies with the amount of stored moisture.

Perhaps the management of plant population has its greatest potential in increasing yield of the newly introduced indeterminate crops. Walton (1976) suggests that greater plant density will compensate for lowered seed yield per plant with later sowings of narrow leaved lupins. Lawn (1979a) foreshadows similar potential for mung beans. An overall view of the present situation supports the conclusion that further exploration of the possibilities of increased yield through population management strategies is warranted. The emphasis of such work should be aimed at determining sowing time x water use efficiency interactions.

Plant arrangement or geometry has not received as much attention in Australia as it has overseas. To some extent, this is a reflection of the restricted range of seeding equipment available, and its lack of flexibility for changes in geometry. The spatial arrangement of a crop can be defined in terms of rectangularity which is the ratio of distance between plants within the row to the distance between the rows. There is a trend for yield per unit area to decrease as rectangularity increases, either as a result of increasing seed rate or row width. The extent of the decrease will be greatest in crops of low plasticity. While some crops have received attention in Australia, this has been mainly confined to those that are irrigated and row-cropped, such as cotton (Constable 1977). The 1980's will see a trend to wider row spacings with the broad acre crops, mainly to facilitate sowing operations under stubble retention systems, and to give greater coverage of area in an effort to increase fuel use efficiency. The effect of such changes of plant arrangement needs urgent attention.

(ii) Plant population, botanical composition and stability of pastures

The practical problem of sowing and maintaining pastures composed of many, few or one species in the sward has perplexed ecologists for many years. Natural grasslands are usually dominated by a few grass species which produce much litter and contain few legumes. The introduction of legumes to improve the nitrogen status of the pasture will give a legume-dominant phase for 3-4 years followed by a build up of grasses as a result of the increase in soil nitrogen (Tothill 1978). Management of the pasture can be viewed simply as the gross output of the community as a whole, whether composed of perennial grasses, legumes or annual weeds. The alternative approach is to study individual plants, their growth and reproduction, which together make up the pasture. The fitness of the individual plant eventually determines the type of pasture and its total production (Harper 1978). Studies of changing numbers of individuals in the pasture can help pinpoint how plants adapt to grazing pressure or stress and complete their life cycle. Knowledge from these studies can be used for management. A few plants have been studied in this way, notably white clover/rye grass (Harper 1978), Siratro (Jomes 1974a; Jones 1979a), white clover in northern New South Wales (Garden unpublished) lucerne (Peart 1968; Brownless 1973) and native grasses (Robinson, personal communication).

Sedentary plants, such as lucerne, leucaena or grasses, which rely on numbers at establishment, are always available for grazing and are sensitive to overgrazing. Management should aim to retain a minimum number per unit area depending on the environment. For example, lucerne survival rates of 45 percent in the South West of N.S.W. can be assured by rotational grazing in favourable seasons (Southwood and Robards 1975). Survival of plants such as siratro may rely on perennial crowns at light stocking rates or seedling regeneration under reduced competition at higher stocking rates (Jones and Jones 1978). Similarly in the subtropics, white clover may rely on stolons to persist through favourable summers or seed set in dry conditions. Survival of white clover seedlings is more influenced by time of germination and seasonal conditions than by stocking rate (Garden, personal communication).

Few studies of herbage plant density in relation to long term DM yield and animal performance have been conducted. Most studies have shown that DM yield of pastures sown at low seeding rates eventually equals the yield of the higher seeding rates, due to compensatory effects of plant size. An important exception is the report by Williams (1979) in S.A. where seeding rate of annual Wimmera rye grass was varied from 1-1024 kg/ha and pastures set stocked with sheep after establishment. In the range 1-32 kg/ha there was a five-fold increase in total pasture, seed and wool production pe ha and sheep survival. At seeding rates above 32 kg/ha (above 1000 plants/m) there was little increase in plant or animal production. The annual carryover of seed reserves and plant density present indicated that the transition from unstable, feed deficient pastures to productive pastures occurred between 16-32 kg/ha of sown rye grass.

Improvements in the criteria for management of pastures at critical times could be expected by further study of the role of stolons, crowns or seed set in the persistence of legumes or desirable grasses in both temperate and tropical environments. In Australia, the role of fertilizer application on botanical changes has been emphasised and the effect of grazing management largely ignored.

High rates of superphosphate application can lead to grass dominance after establishment in some environments e.g. tablelands of N.S.W. (Wolfe and Lazenby 1973), southeast Queensland (Blunt and Humphreys 1970) and coastal N.S.W. (Mears and Barkus 1970): Superphosphate has also been shown to be important in maintaining ryegrass in competition with native grasses (Cook et al. 1978). Alternatively, superphosphate at moderate rates, effectively promotes legume growth in most environments in Australia e.g. white clover in northern N.S.W. (Wolfe and Lazenby 1973; Havilah et al. unpublished) Townsville stylo in northern Australia (Shaw 1961; Ritson et al. 1971) and Desmodium species in southeast Queensland (Bryan and Evans 1973).

The stability of pasture and botanical composition changes are sensitive to stocking rate and grazing management. On the northern tablelands of N.S.W. Cook et al. (1978) studied pasture degeneration and found that in the absence of continuous superphosphate application native and weed species invaded the pasture. Intensive grazing during the winter/spring period allowed the invasion of red grass and other native grasses while lax grazing or pasture spelling in this period encouraged ryegrass.

In northern Australian Townsville stylo associates well with native grasses but pastures require to be heavily grazed during the opening rainy season to stop perennial grasses from shading the seedlings (Ritson et al. 1971; Gillard and Fisher 1978). In ungrazed pastures, Townsville stylo is rapidly eliminated. The competitive characteristics of annual grasses and Townsville stylo in the Northern Territory were studied by Torssell (1975) by dividing the pasture life cycle into 3 consecutive phases, germination - establishment, growth and seed production. He suggested that Townsville stylo establishment was favoured by short opening wet periods and drying, while improved soil fertility and moisture favoured Digitaria ciliaris. The system was basically unstable but could be improved by replacing Townsville stylo with S. hamata or S. scabra and perennial grasses. The clearing of woodland was not justified unless crops were to be introduced.

A cardimal weakness of perennial legumes in coastal pastures of southern Queensland and northern N.S.W. is their poor persistance in grazed pasture e.g. siratro ,desmodium and glycine (Humphreys and Jones, 1975; Bryan and Evans 1973; Colman and Mears 1975). On the "wallum" in southeast Queensland this lead to a 50 percent decline in animal production over five years (Evans and Bryan 1973).

The recent substantial increases in cost of fertilizer and pasture establishment emphasise the need for further research on management strategies which encourage legume persistance at low fertilizer levels e.g. imposing rest periods at critical times for potentially productive species, or finding species which tolerate "mismanagement"; e.g. Aeschynomene falcata (Wilson, personal communication). The particular gaps are management studies to maintain Stylosanthes in combination with perennial grasses and perennial legumes in the subtropics.

Plant structure and the environment

Opportunities for the agronomist to alter plant structure or crops by management techniques are limited. It has been recognised that if the leaves of crops were borne at an upright angle, in contrast to being horizontal, then a greater area of leaves on a particular plant would receive a higher light intensity. This increased light penetration would give higher daily canopy photosynthesis (Moss and Musgrave 1971). The production of crop plants with this characteristic is largely in the hands of the plant breeders. However, the objective of higher productivity would be well served by an increase in activity directed toward quantifying any increase in efficiency achieved by more erect leaved cultivars within each crop. This would encourage breeders to include such a characteristic in their concept of the ideal ideotype.

The use of dwarf cultivars of crops has been widely adopted in those crops for which they are available and under circumstances where their use is appropriate. The use of such cereal varieties, has played an important role in increasing yields in the last ten years. There is still scope for greater employment of such types in the indeterminate crops, particularly in the irrigated situation. Under dryland conditions, seasons of restricted rainfall can result in crops too low to harvest if height-shortened cultivars are used. The importance of plant structure and distribution of leaves in the canopy of pastures and animal production, has been shown in recent studies by Allden and Whittaker (1970), Stobbs (1973a, 1973b), Chacon et al. (1978). Sheep and cattle show remarkable abilities to graze plants selectively. The physical characteristics of the pasture markedly affect the ability of the herbivore to graze. Cattle draw herbage into their mouths with a curling sweep of the tongue and tear it from the plants. Usually uppermost, accessible green leaf is eaten in large mouthfuls, followed by stem with leaf. As the amount of feed offered declines, more dead material and stem is eaten, grazing time increases and bite size falls. As an adult steer can selectively harvest about 30-70 kg of fresh pasture each day, the accessibility and nutritive value of the upper parts of the plant set the upper limit to production per head.

Measurements of the vertical distribution of herbage (leaf and stem) from the top canopy to ground level show that tropical pastures give swards which are loosely packed (14-200 kg DM/ha/cm) compared with temperate swards (160-400 kg DM/ha/cm). Bite size and quantity of leaf in each bite is positively related to leaf yield percentage and bulk density of living green leaf, particularly in the upper layers of the pasture (Chacon et al. 1978). For cattle, bite size of ingested herbage can vary from 79 to 165 mg OM (organic matter) per bite depending on intensity of defoliation (Chacom and Stobbs 1976). For temperate pastures bites can be as large as 800 mg OM (the critical bite size to achieve 3 percent of bodyweight is 300 mg OM). Chacon et al. (1978) reported mean sward bulk densities of setaria and pangola of 202 and 206 kg DM/ha/cm.

If the physical characteristics of the sward affect bite size which in turn accounts for about 80 percent of intake of digestible nutrients, studies in management should aim to:

- produce pastures with a high leaf bulk density in the uppermost canopy.
- defoliate only to a level which allows easy harvesting by the animal.
- integrate defoliation practice with fertilizer applications to produce dense leafy swards of grass and legume.

In temperate regions this requirement would be best achieved by sowing grasses with a large tiller population (by reducing seeding rate or defoliating to promote tillering). In the subtropics, legumes will be needed to increase overall nutritive value of the pasture. Leaf yield can be maximised by lenient stocking and by selecting for short statured, leafier strains of grasses.

Plant development, growth regulators, changes in chemical composition and nutritive value

The use of growth regulators in agriculture has been thoroughly investigated, as it would seem to offer an attractive means of increasing yield. In Australia, Low and Carter (1972) recorded yield increases in wheat from CCC application but the response was largely associated with a reduction in plant height. Where excessive height and subsequent lodging are not considerations, this growth regulator has no practical effect of yield. The advent of semi-dwarft cultivars has reduced the potential importance of this chemical under Australian conditions. Gibberellic acid pre-treatment of grain sorghum assisted emergence under low soil temperature conditions (Shang-tien Yen and Carter 1972). However, the overall promise of the growth regulators to improve crop yield appears extremely limited. Similarly for pastures such as kikuyu, use of gibberellic acid to produce out-of-season growth (Lester et al. 1972) is not warranted. New chemicals at present under investigation in other countries may change this situation in the next ten years.

Nutritive value of the plants in pastures declines as development proceeds from the juvenile vegetation stage, through flowering and seed set to senescence. Mature whole plants contain lower percentages of nitrogen and digestible organic matter and a higher percentage of crude fibre than younger plants. Mobile elements such as nitrogen, phosphorus, potassium, sodium and sulphur tend to be progressively translocated to the growing points or seed, while calcium, magnesium and some trace elements remain in older tissues.

Many papers have been published and research is continuing on relationships between nutritive value and factors such as digestible energy, digestible protein, degradability of protein, carbohydrate status, products of fermentation, cell wall constituents, lignin, silica, phosphorus, sulphur, cation balance and toxic substances in the feed. The level of animal production is proportional to the daily intake of digestible dry matter; quantity and digestibility of feed are involved. Intake and digestibility of herbage are depressed when plants are deficient in nitrogen or minerals and when fibre content increases with maturity (Stobbs 1975).

Large differences in intakes and digestibility occur between and within grass species and in the rate of decline of nutritive value with age. In tropical grasses, young leaves contain higher percentage of nitrogen than older leaves or stem (Wilson and t' Mannetje 1978). In general concentration of nutrient elements declines in various organs in the order; seed, leaf lamina and primordia, leaf sheath, stem, roots and dead material. Practices which maximise leafy growth or seed yield will increase quality. Both voluntary intake and digestibility are higher with temperate and tropical legumes than with tropical grasses.

In theory management practices should aim to constantly return the plant to a juvenile stage of growth, while at the same time maintaining am adequate amount on offer. In practice this is difficult to achieve because of selective grazing by the animal leading to some fractions of the sward being rapidly eaten and the less palatable or inaccessible parts being left to mature (Arnold 1964). Attempts to interpose management practices such as deferred grazing at critical times e.g. autumn rests for annual Mediterranean pastures (Brown 1976) or conservation (Hutchinson 1966) have mostly failed to improve animal production. It is known that defoliation will redistribute nutrients e.g. nitrogen (Mears and Humphreys 1974), organic compounds (Marshall and Sagar 1965) phosphorus (Ozanne and Howes 1971), mainly from storage or structural organs to growing points. The only practical way to achieve this end is to force the animal to utilize a greater proportion of the pasture by simply increasing stocking rate. As a large number of stocking rate experiments have been conducted in temperate Australia and more are under way in tropical environments, results need to be interpreted at the farm level.

Defoliation of crops and regrowth of herbage

Defoliation as a pathway toward higher crop productivity has not received much attention. In some areas of the cereal-sheep zone, dual purpose grazing and grain crops, usually oats and to a lesser extent barley, are used to achieve high profitability. In fact, varieties of oats have been produced that require grazing to maximise grain yield. Even in grain crops not specifically bred for ability to recover after defoliation, strategic grazing under certain seasonal conditions cam be advantageous. Dann et al. (1977) found that wheat and barley yields could be increased by grazing in seasons of high rainfall when lodging and disease were troublesome. Further work along these lines could prove profitable, indicating biologically more profitable methods of crop production in the 1980's.

Chemical defoliation to hasten grain maturity may have some role to play in indeterminate crops, but there is no local research experience.

The subject of defoliation in relation to grazing management has been reviewed by many grassland workers. This has led to controversy and various schools of thought on the bases of management; particularly rotational or continuous grazing, effects of cutting, stocking rate and other factors affecting plant growth (Daview 1954; McMeekan 1960; Wheeler 1962; Humphreys 1966; Morley amd Spedding 1968; Arnold 1969; Willoughby 1970; Walshe 1975; Humphreys and Jones 1975; Watkin and Clements 1978; Morley 1978 and Harris 1978).

Woodman and associates in the U.K. laid the foundations for pasture management by showing dry matter (DM) yield and quality were inversely related. As cuttimg interval increased, DM yields were improved but quality and leafiness declined as the pastures matured. By extrapolating the results of cutting experiments, agronomists world-wide diligently recommended rotational grazing against set stocking in many mesophytic and subtropical environments. Australian workers were the first to systematically compare rotational versus continuous grazing in many pasture types in the decades 1940-60 and surprised themselves and many overseas workers when continuous grazing systems equalled or out-produced rotational grazing, when animal production was measured; e.g. phalaris/subclover/ lucerne (Moore et al. 1946; Morley et al. 1969). Rotational grazing was only superior (5-10%) to continuous grazing at higher stocking rates with dairy cows (McMeekan and Walshe 1963). Lucerne was the sole exception; whenever tested lucerne required a period of protection from grazing (Cameron 1976).

Research workers were slow to realise that stocking rate (number of animals/ unit area) was the most important variable affecting pasture productivity and animal output (exchanges between McMeekan and Griffith - Davies, personal communication, Mott 1961; McMeekan and Walshe 1963). A spate of field work and intense interest in the theory behind stocking rate x individual animal performance relationships, followed these papers. Agronomists were exhorted to compare species in management systems over a range of stocking rates, with a minimum of three rates (Wheeler 1962; Walshe 1975) or at stocking rates which markedly decreased animal gain per head (Coniffe, Brown and Walshe 1970; Jones and Sandland 1974). A large number of stock rate experiments were conducted without any attempt to measure changes in the pasture composition over time.

Defoliation practices which maximise dry matter production have been determined experimentally for different pastures. Ideally frequency of defoliation should be set at intervals allowing maximum growth rate and intensity should be at a level which leaves maximum stubble for regrowth (Harris 1978). Other factors affecting regrowth have been proposed as criteria for pasture management e.g. leaf area index (L.A.I.) (Brougham 1956), residual L.A.I. (Humphreys and Robinson 1966) or carbohydrate reserves (Graber et al. 1927, Weinmann 1961). These are not universally accepted as determinants of pasture growth and all suffer from being difficult to measure in practice.

Examples showing the effect of various defoliation treatments on pasture growth are given in Table l.

In general growth of perennial, subtropical legumes and lucerne responded to longer intervals between defoliations, less intensive defoliation or lower stocking rates. White clover and ryegrass could withstand heavier utilization without suffering severe growth penalties. As nitrogen yield of tropical pastures is dependant on DM yield of the component legume, management practice should aim to maximise the legume components. In many environments defoliation by the grazing animal varies throughout the year (from light, intermittent to heavy continuous) because of diet selection, physiological state of the animal, uneven grazing and pasture growth rates. In most cases control of defoliation (rotational vs continuous grazing) on a year-long basis has failed to show major differences in plant growth let alone animal production. Lucerne is the only pasture species which definitely requires rotational grazing, a finding reported

in repeated experiments from many environments. However, the control of defoliation at certain critical periods in some pastures could maximise legume dry matter yield and ultimately animal production, especially when the pasture species is under stress. Examples are:

In the dry tropics, early heavy grazing may favour the regeneration of the annual Townsville stylo by reducing grass competition (Gillard and Fisher 1978).

In the subtropics, siratro (and other perennial legumes) may require longer intervals between grazing in spring (6-9 weeks) and grazing to a threshold stubble height of at least 20-30 cm throughout the grazing season (Roberts 1979).

Conversely, white clover grown with vigorous subtropical grasses requires heavy continuous grazing at increased stocking rates in summer to persist (Jones 1979b).

In temperate Australia most attempts to maximise plant yield through management have generally failed to increase animal production (Morley et al. 1969; Willoughby 1970; Brown 1976; Fitzgerald 1976) although marked changes in feed availability between winter and summer were recorded.

Harvesting techniques

The efficiency of modern grain harvesters has reached a high level. Losses of grain through the machine have been very much lowered with the use of electronic grain monitoring devices. This improvement, coupled with the efforts of plant breeders to reduce pre-harvest shedding has reduced grain losses. It has not been possible to reduce the shattering tendency in all grain crops, as a number have an inherent tendency to form abscission zones either adjacent to or within the fruiting body. The narrow leaved lupin is an example of a crop with this characteristic having a tendency to shed whole pods at maturity. Rapeseed is another crop in which almost total seed loss can occur.

There are two approaches to this problem that could result in increased yields. The use of desiccants before the zones of abscission have formed is one avenue that as yet has received little attention. Windrowing or swathing of crops, a common practice in the short growing seasons of the northern hemisphere, could also find Australian application, but for a different purpose. This practice could overcome the problem of shattering, but further work is required to measure effects on grain yield and quality.

Table 1 examples of the effect of defoliation treatments on dry matter yield of temperate and tropical pasture species selected from the literature

Defoliation practice	Rye grass	White clover	Lucerne		Tropical	Siratro	
	Holliday et al.[2] (1965)		Langer et al. (1965)		Bryan et al. (1965)	Jones (1974a)	Jones (1967)
Cutting Interval 2-3 weeks	M[1]		M				
4	M				L[3]	M	F
8	H		H		M	M	L
12					H	H	M
16 or more						H	H
Grazing Interval	Lane (1971)	Campbell (1969)	Southwood et al. (1975)	Smith (1970)		Jones (1979)	
Less than 3 weeks	H	M	H	F		M (1.8 & 2.3	
3-6	H	H	H	H		H animal/ha)	
over 9						H	
Defoliation Intensity	Brougham (1959)	Brougham (1965)	Langer et al. (1965)			Jones (1974a)	Jones (1974a)
Below 10 cm	H	H	L			L 4 wk	H 16 wk
Above 10-20 cm	H	M	M			M	M
					Humphreys et al. (1966)	Jones (1974b)	
Residual LAI < 0.2					M[4]	M	
0.2-0.7					H	H	
> 0.7					H	H	
Root carbohydrate status Low					H		
Medium					M	M	
High					H	H	
Stocking rate steers/ha	Alder et al. (1968) N336 kg/ha	Alder et al. (1968) No kg/ha	Smith (1970)		Mears et al. (1974)	Jones (1974c)	
0.5-1.0						H	
1.0-2.0			H (2 w/ha)		M[5]	M	
2.0-2.5	H	H				L	
2.5-3.0	H	H	M (3 w/ha)			L (F)	
> 3.0	H	H	M (4 w/ha)		H		
			L (5 w/ha)				

1 F = Failed to persist L = < 35% of maximum yield M = 35-75% maximum yield H = > 75% maximum yield
2 ( ) Reference First author name only 3 Pangola grass 5 Kikuyu 4 Green panic

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