Experiences of Pasture and Crop Production

J.L. Davidson

CSIRO Division of Plant Industry, Canberra, ACT 2601

Since the organizers have been kind enough to award me this medal, I have assumed that they would not be so cruel as to expect me in retirement to present a scientific paper. So I am taking the liberty to treat this oration literally as that: a discourse, a talk, and because I am reluctant to speculate about the experiences of others, I will concentrate on work in which I have been involved. In doing so, I hope to illustrate that a career in agronomy becomes a mystery tour in agriculture. It will be more so and more exciting in the future, because of the increasing rate of changes in population trends, in world eating preferences, in industrial processing of primary products, in world political alignments and trading blocks, and especially in technology and scientific methods. These and many other influences will surely radically change the priorities of agronomists who are young today, and they, too, are likely to move from a guided start to points of indecision and on to an end that would have been unexpected at the beginning.

The Donald Medal has the nice touch that it is awarded to aged agronomists, around retirement. However, it is a myth that ageing is associated with invaluable experience and acquired wisdom: with age, many experiences are forgotten, and in place of wisdom, we seem to acquire only disabilities. But, apparently, by dint of age, we also acquire some note through associations that young people have been denied. The only note that I could lay claim to, is that in my youth I watched Don Bradman bat, and that I once worked with Colin Donald. Both events seemed to come together during the second test match against South Africa last season, when I heard Richie Benaud, once a great Australian spin bowler, recount that he once told Keith Miller, one of our greatest fast bowlers, that his one regret in cricket was that, unlike Miller, he had never had the opportunity to bowl to Bradman. "Son", said Miller, "we all get lucky breaks in life, and that was yours".

My lucky break in agronomy was that Colin Donald left CSIRO, where he had been Assistant Chief in the Division of Plant Industry, to become Professor of Agronomy at the Waite Agricultural Research Institute where I was a post-graduate student; he immediately became my supervisor for a project on defoliation effects on subterranean clover. All who knew Colin Donald will remember him as one of nature's gentlemen, as well as being our greatest Australian agronomist.

Before his arrival, I knew of him as an outstanding pasture agronomist and our one world figure in the field of plant competition. He had also found and emphasised that subterranean clover pastures had a ceiling yield of 9 t/ha (7). It was another, later step to argue that this must necessarily mean a balancing of photosynthetic gains by losses from respiration and decay.

The Deniliquin Experience

When I joined CSIRO's Division of Plant Industry at the Regional Pastoral Laboratory, Deniliquin in southern NSW in 1956, I was fortunate to find there a young genius, John Philip. Through his mathematical skills we were able to illustrate how light intensity should decrease with increasing depth in a canopy of horizontal leaves, such as in a subterranean clover pasture, thus the way in which photosynthetic and respiration levels would vary with depth in the canopy, and the way in which net photosynthetic rates should therefore change as leaf area index (LAI) increased. This mathematical model (5) also offered a theoretical assessment of how pasture production would vary under grazing if it were possible to control LAI.

That theoretical exercise led to an attempt to control LAI removal by sheep and measure effects on production. We began by making a muzzle with prongs that fitted the face of sheep to control the height of grazing. But when the first animal fitted with the prototype escaped from the grounds of the Deniliquin laboratory, we had to broadcast radio appeals for the return of a muzzled merino wether. Our OIC at the time was sensitive to any criticism or embarrassment, and his discomfort became unendurable as he contemplated jibes from the locals about the ferocity of CSIRO merinos and the fear of CSIRO staff for sheep. The project was abandoned, and my attempted entry into the field of grazing management had failed.

The Deniliquin laboratory had been established primarily to tackle problems that confronted local producers, and I was able to take refuge in working on regional problems, the chief one in the late 1950s being the failure of pasture seedlings to emerge from irrigated clays. On this problem I was lucky to work with one of our foremost soil scientists, Jim Quirk, then with CSIRO Division of Soils. Most of the riverine clays were sodic, so they dispersed on wetting and caked like concrete on drying. We were able to show that they could be treated effectively by large quantities of gypsum broadcast, or by much smaller quantities dissolved in the irrigation water (6).

In order to improve pasture production we also had to become involved with species and nutritional trials, and for me, the Deniliquin work was important in confirming that agronomy offers enormous scope both forhelping farmers and stimulating academic studies as it leads agronomists into many branches of science that impinge on agriculture and which are represented at conferences of this Society.

Throughout the 1950s, increased understanding of yield differences in pastures and crops was based largely on the classical growth analysis approach that had been adopted by English plant physiologists, beginning with Blackman's concept of relative growth rate (1) and perhaps culminating with Watson's summation paper, "the physiological basis of variation in yield" (11).

By the 1960s, physicists and mathematicians were making prominent contributions to biology, and especially to crop and pasture production, largely by demonstrating advantages of mathematical models over earlier approaches. One notable example was Monteith's model of light interception and crop growth (10). Until then, it had been assumed that the much higher levels of radiation were responsible for the higher crop growth rates of sugar cane and maize in the tropics than of sugar beet in England. Monteith's model established that a lower resistance to diffusion of CO2 from atmosphere to carboxylation in sugar cane and maize was the reason for their higher rates of photosynthesis and production. A year later, Hatch and Slack identified the C4 photosynthetic pathway in sugar cane (8).

Despite the value of mathematical models, nobody involved with field work on grazed pastures could accept that pasture growth could be described adequately as a combination of physical relationships between leaf area and CO2 exchange: often there was no leaf remaining following close grazing. And in response to frequent or continuous defoliation, pastures completely alter the structure of their leaf canopies and become far less affected by defoliation than previously ungrazed ones. It was the control of regrowth that intrigued me and led me to work with Fred Milthorpe at Nottingham. Understandably, the most drastic effect of severe defoliation we found was severe reductions in all measurable functions of the root system, including the uptake of nutrients (4). So in recent years I have been intrigued by the ability of certain genotypes of wheat to recover rapidly from hard grazing without displaying leaf pallor. We have had to leave these spectacular differences for others to study.

It was the challenges of research in grazing management that drew me to the Canberra headquarters of our CSIRO Division in 1966. Where grazing animals are involved, different compositions of pastures, different field conditions and different management practices combine to produce an almost infinite range of plant experiences and responses which are difficult, if not impossible, to identify, measure or reproduce, and which are not readily examined by standard, replicated trials. In the 1970s, a modelling approach developed as the accepted alternative. Through their access to increasingly powerful computers, agronomists had a new research tool which is now used extensively in management as well.

In the early 1970s, a crash in wool prices was quickly followed by another in cattle prices, and Australian graziers became victims of a severe rural depression.? The consequent collapse of funds for rural research threatened the careers of many scientists and forced agronomists to reconsider the aims and value of their work. I no longer believed that improved grazing management could provide an effective solution to the finacial problems of graziers.

Winter crops for high rainfall zones

It was my ignorance of the agricultural economy that led me to the then Bureau of Agricultural Economics (BAE) to identify producers who were in greatest need of research help. Every year the BAE identified and mapped three national agricultural zones on the basis of land use recorded by field officers. I learned that, at that time, about 50% of Australia's bona fide primary producers were in the high-rainfall zone, and their incomes were consistently far lower than those of their counterparts in the other zones: crisis or no crisis, they were most in need of help. In terms of average incomes, the wheat/sheep zone was the most prosperous zone, primarly because of its mixed farming. The other zones were both grazing zones: like the pastoral zone, the high-rainfall zone was identified by the absence of crops.

From the considerable data available on topography, soils, climate and farm size, there appeared to be no good reason for high-rainfall zone producers being restricted to grazing enterprises. Indeed, winter growing crops, including cereals, must be expected to yield best in the coolest parts of the zone, including the northern, central and southern tablelands of New South Wales, eastern and southern Victoria, Tasmania, the south-east of South Australia and the south-west if Western Australia. High yields of wheat are dependent on cool conditions for grain development which result in a long period of grain filling, and the longer the daylength during grain filling, the longer the period of photosynthetic gain and the shorter the dark period of respiratory loss. Clearly, if grains develop under cool, moist, summer days, following a long growing season, the yields of wheat should be maximised. Thus England produces about as much wheat as Australia, at an average of 7.5 t/ha, or five times average Australian yields. In England, grain development occurs in mid-summer at a daylength of about 18 hours. These conditions cannot be matched in Australia, but they are approached in the cool parts of the high-rainfall zone, especially in Tasmania: these must become our most productive cropping regions.

The coldest parts of the high-rainfall zone are the tablelands of New South Wales. Because there pasture growth virtually stops in winter, feed shortages in winter invariably limit production of meat and wool. If graziers are to be attracted into wheatgrowing, the winter feed situation must not be made worse: ideally, producers must be offered dual-purpose varieties that can provide as much feed as their permanent pastures would offer for winter grazing, and recover from grazing to produce high yields of grain in summer. We needed to find out what types of wheat could do this and what management principles should apply. And we also needed a breeding program to provide genotypes suitable for our target zone.

The first necessary step was to examine the variation available among world wheats. Because flowering time is of crucial importance in determining the suitability of any grain crop for a particular environment, we measured, in over 100 varieties drawn from many countries, responses to vernalization and photoperiod (2) which together largely determine flowering time. We then selected a sample of 24 varieties that covered all the variation we had found among the varieties tested, and then examined their suitability for grazing plus grain.

It is time of ear initiation that determines the suitability of wheat for winter grazing. In the vegetative state, the growing point, or shoot apex, is at the very base of the shoot, below ground level, and protected from grazing and frost. But following ear initiation, stem extension rapidly raises the growing point above ground where grazing can destroy it, with drastic effects on grain yield. Therefore the maximum amount of feed that can be grazed with safety is the amount present on the day of ear initiation, or double ridge stage of the shoot apex. For that reason, we measured herbage availability from our sample of world wheats on the day they initiated ears in a number of environments obtained from different sowing times at different sites. From each site we got very consistent results.

An important point is that wheat offers invaluable variation in rate of floral development, with ear initiation varying from 3 weeks to 5 months after sowing in March (Fig. 1). As every variety reached initiation, the amount of dry matter it had produced indicated that wheat, to ear initiation, grows at a remarkably constant rate: at Bombala on the southern tablelands that was 30 kg/ha/day from a mid-March sowing, and just 1 kg/ha/day from a mid-May sowing, which is useless if winter feed is required. From early autumn sowings, 3-6 t of dry matter can be available for grazing in winter from vegetative wheat crops. A consistent and surprising feature of the results was that the constant growth rate continued right into and beyond mid-winter in undisturbed crops, although mean temperatures fell from 15 to 5?C, and growth of grazed pastures stopped. If these crops had been grazed in May, their growth rates would have fallen to about the 1 kg/ha/day level which resulted from the May sowing.

Thus, the first principle of management for dual-purpose wheats is to sow early, ie. in late summer or early autumn, to achieve high rates of growth. The second principle must be to graze late in order to achieve a long period of growth, ie. leave grazing until at least early or mid-winter when feed is most needed. Since spring wheats initiate ears earlier than winter wheats following early sowings, only winter wheats can then be grazed safely in winter. So the third management principle must be to choose long-season winter wheats for early sowing and late grazing: these can be grazed safely until late winter, for they will not initiate ears until then, while the earliest spring variety will initiate ears within three weeks of sowing. In our study, that variety was William Farrer's Sunset, which is virtually insensitive to both vernalisation and photoperiod, and therefore only temperature restricts its progress to ear initiation.

In warm conditions, Sunset's rate of development is so fast that from the March sowing at Bombala, it was in ear by late May, before some spring varieties, and any winter variety, had even reached ear initiation. And while crops that were still vegetative grew at an average of 30 kg/ha/day, Sunset grew at more than 3 times that rate to produce 10 tonnes of dry matter per hectare, compared with 3-4 tonnes available from vegetative crops.

For the same spring varieties grown at a different site, Canberra, the same picture is evident for dry matter production at ear initiation, ear emergence and grain harvest: a constant growth rate for all varieties until ear initiation, followed by much faster growth rates during the reproductive phase (Fig. 2).

The varieties which had reached ear emergence when other spring varieties were still vegetative, had produced up to 10 t/ha of dry matter while the vegetative crops had produced only 2 t/ha. The spectacular growth rates normally associated with spring have little to do with environmental differences between autumn and spring; they depend upon plants being in the reproductive phase of development. The high growth rates of spring are reproduced in autumn if crops approach flowering.

This finding allows us to increase substantially the amount of feed available for winter grazing without breeding effort. Sunset, or a similar variety, is mixed with a long-season winter wheat. The spring component of the mixture is virtually eliminated by grazing in winter, but the winter wheat component, on recovering from grazing, can form a complete canopy and grain yield need not suffer from the inclusion of the spring wheat (3). So the fourth principle of management should be to mix winter and spring wheats to increase winter feed supplies: no permanent pasture can match the growth rate of such crops.

As different genotypes initiate ears they move into a faster rate of above ground dry matter production, so there is an obvious association between rate of development and rate of above ground growth. The range of times to initiation, hence to flowering as well, can be traced to differences in the growth rate of the tiny, veg- etative shoot apex. A student who worked with us for a year found that all the varieties he examined initiated ears when their shoot apex reached a size of 1/ 8th of a cubic millimetre in volume. Irrespective of whether they were vernalized or not, or experienced long or short photoperiods, they all eventually passed ear initiation (9). Floral development, therefore, is simply a function of the rate of growth of the shoot apex. The association between growth and development presumably results from a link between rate of crop growth and rate of shoot apex growth: this could conceivably be a single hormone which influences both. Vernalization and long days increase the growth rate of the shoot apex and so accelerate flowering.? Unlike spring wheats, which dominate in the Australian wheat belt, winter wheats will not produce ears if they never experience vernalizing temperatures (9). This is simply because their developing ears continue to grow so slowly that they never emerge from the sheaths of leaves that age and senesce around them; ear initiation ends the production of new leaves which could continue to support slowly growing ears.

Because of its controlling influence on growth and development, the shoot apex of wheat would seem to offer biologists an exciting entry into fundamental studies of the determination of cell growth and cell shape.

Winter wheats available

Our work priority was to provide winter wheats that would be suitable for grazing plus grain in the cool parts of the high-rainfall zone. In the mid-1970s we began a breeding program that is still based on crosses between English winter wheats, then and now the highest yielding varieties in the world, and two spring wheats from CIMMYT in Mexico. The Mexican varieties were used to reduce photoperiod sensitivity which makes English wheats too late in flowering for the lower latitudes of Australian environments, and from this program we have selected only awnless, winter wheats. Until now, it has taken us 15 years from the time we make a cross until a variety from it is available for commercial sowings, seven generations and years to produce a true-breeding line, and eight years of multiplication and testing. So far we have released Lawson, Paterson and now Gordon, which is rust-resistant Lawson, and we are aiming at soon releasing varieties resistant to Barley Yellow Dwarf Virus, which is the greatest disease threat to early-sown crops.

In its first season of commercial production, Lawson near Ballarat yielded 9.5 t/ha of grain, while other crops of it in southern Victoria equalled the previous highest-reported yield from the Australian mainland of 7.8 t/ha, and last summer a crop of Paterson near Ballarat was verified as yielding 9.9 t/ha. In the tablelands of New South Wales, grain yields as high as 7 t/ha have been recorded following winter grazing, which itself has been valued as a profit over production costs of $250/ha at current prices. The grain yields have confirmed that the coldest parts of agricultural Australia have the highest yield potential, and winter wheats from other sources, to date Declic and More, have been added to varieties available for southern Victoria which is the region of most rapid extension into wheatgrowing. To date, the varieties are used to provide feed grains for rapidly growing domestic and Asian markets, and milling varieties should be a future option.

Lack of high-yielding varieties no longer restricts wheatgrowing in the high-rainfall zone, but poor agronomy does. For those involved, which now include State Department agronomists, private consultants, agricultural merchandising firms, The Australian Wheat Board (AWB) and the Grains Research and Development Corporation (GRDC), the difficulties of converting graziers into good wheatgrowers are proving a challenge. For meat and wool producers, the need to control weeds, supply high rates of replacement nutrients and grapple with alternative sowing practices is a new experience which often leads to poor crops. Another difficulty is that they have few options yet for productive rotations.

Achieving change

Frustration from recognising both the great potential for cropping in the high-rainfall zone and the need to overcome major agronomic problems led to a large group of Victorian farmers joining together to form Southern Farming Systems. With the closest collaboration and support from Agriculture Victoria agronomists, Chris Bluett and Bruce Wightman, this organization has being doing its own research into the most urgent problems facing crop production. Its success in dealing effectively and simply with waterlogging, fertilizer requirements and cropping alternatives is leading to a rapid expansion of wheatgrowing in the Victorian high-rainfall zone. As a self-help organisation which translates successful trials into immediate farm practice, Southern Farming Systems is revolutionising agriculture in its region. All agronomists should become familiar with the nature of this organisation and its success: it may well be establishing a model that will be followed throughout southern Australia wherever agronomic research is needed to bring about significant, agricultural change.

It may always be difficult to bring about significant agricultural change. Our attempt simply to provide red-grained feed wheats for high-rainfall zone producers met hostile resistance from several influential quarters. Our varieties reached producers only when the Australian Wheat Board declared that there was a huge and expanding need for feed wheats, and that red seed coats were quite acceptable for these. It also determined that it would promote the production of wheat in the high-rainfall zone, and since then, it has financially supported our project.

Until then, the project had been entirely dependent upon support from four groups of willing collaborators, all of whom recognised the potential of high-rainfall cropping and did whatever they could to help. They were, firstly, close colleagues in the Division of Plant Industry; secondly, agronomists of New South Wales Agriculture and Agriculture Victoria stationed in or adjacent to the high-rainfall zone, thirdly, a group of volunteer farmers in New South Wales, and fourthly, the staff of the Plant Breeding Institutes of The University of Sydney. No project could have had more valuable support.

As we look back on our working lives we shall all find that agronomy has presented us with both challenges and opportunities to influence Australian agriculture. It prompts us at least to consider a wide range of important issues: in our project these varied from prospects of domestic and world markets for agricultural products to the control of growth rate of the growing point of wheat.? And it can lead to productive careers across that broad spectrum of choice. I have tried to choose a path that would be helpful to primary producers, hoping that it should therefore be also of some benefit to our country.? I have always found my main reward in primary producers being grateful, helpful and patient. It has been a privilege to try to help them, and it is another and unexpected privilege to be given this medal.

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