SOILS AND PASTURES

Agronomy: A Veterinarian's Refresher

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1 Introduction

The purpose of this paper is to review some of the basic physiological and morphological principles that underpin pasture management decisions and apply these principles to the management of pastures for deer. The rationale for taking a principles first approach is that markets and seasons are constantly changing which call for varying pasture strategies. In addition there are a wide range of pasture and fodder species and cultivars to choose from and understanding how they grow will help make appropriate choices.

The cornerstone of pasture management is feed budgeting; matching the supply of feed to the demands of the animal system. The key features of the deer production system are fawning in early December and lactation demand which reaches a peak in late January and continues until weaning. It is desirable to get those weaners off at a killing weight within 12 months (Barry *et al.*, this proceedings) which puts a premium on high quality feed being available in Autumn and Spring. Also, velveting stags have a high feed demand in late Winter and Spring.

To match supply of feed to demand it is first important to appreciate the environmental factors that determine pasture growth rates. Temperature has an overriding influence on plant growth. Following this, soil moisture is important because of both its seasonal impact but also because its variability. Appropriate strategic use of nitrogen fertiliser is explained.

The choice of species to grow ranges from permanent pastures which provide cheap feed the year round to fodder crops that target a specific feed gap. This range of uses is covered by the traditional ryegrass/white clover pastures which is tolerant of hard grazing and shows good persistence. Species like red clover and chicory produce abundant feed for six months over summer but need careful management and persist only for a few years. Annual fodder crops like the Brassicas are once only options that are part of a cultivation rotation but can produce high yields. Differences in plant morphology and physiology distinguish pasture and fodder crops, their ability to grow again after defoliation, and the quality and quantity of feed that they offer.

Finally, the low cost of permanent pastures is due to the ability to defray the high establishment costs over many years. Managing for pasture persistence is important.

2 Environmental factors

Environmental conditions, sunlight and temperature, and resources, water and nitrogen, have a predominant effect on the growth of plants.

2.1 Light/Temperature

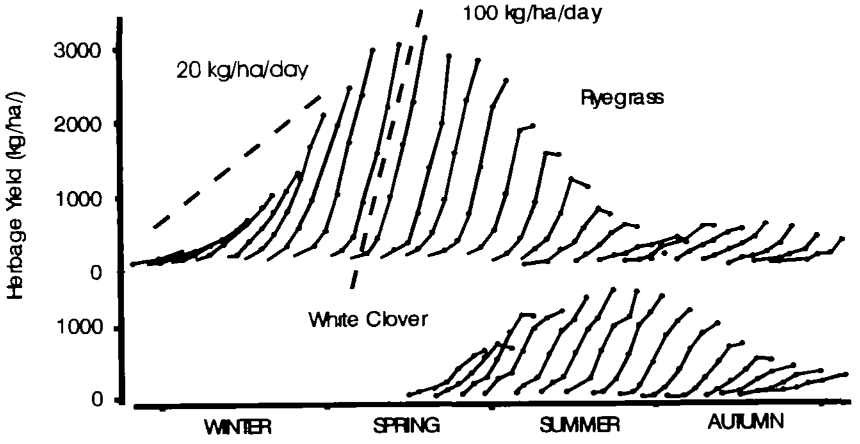

Figure 1 *Seasonal growth of ryegrass and white clover The dashed lines represent growth rates of 20 and 100 kg/ha/day (Adapted from Brougham, 1958)*

The effect of temperature is shown graphically in Figure 1. These data were generated by locking up a ryegrass and white clover pasture at 2 week intervals and sampling every two weeks. The data have been smoothed to take out some day-to-day climatic variation. The low growth rates in winter (< 20 kg/ha/day) contrast with the higher growth rates in spring (~ 100 kg/ha/day). The drop in the growth rate of ryegrass in summer is related in part to its physiological development as ryegrass becomes reproductive in summer, and part to the higher temperatures. Ryegrass has an optimum temperature of ~ 18°C and its growth rate declines at higher temperatures. This slowing of ryegrass allows the white clover to flourish as it is normally suppressed by the vigorous growth of ryegrass in spring but it has a high optimal temperature for growth at ~ 22°C that is better suited to growth in summer.

The low total yield in winter is due to both the slow growth rates and to the low level of radiation.

2.2 Moisture

Moisture stress in pastures and crops occurs when the water loss from plants, evapotranspiration, exceeds the combined supply from the soil reserve and current precipitation. Available soil water reserves range from 75 to 100 mm with deeper rooted fodder plants like chicory, red clover and lucerne having access to more and therefore avoid water stress better than less deeply rooted species. In summer water losses can reach 5 mm/day. These rates can exhaust the soil reserves in two to three weeks. Once plants become water stressed production slows down and even stops. Plant survival then becomes a key issue. Species and cultivars vary in their resistance to moisture stress, the maintenance of production into a stress period, and in their resilience to moisture stress, the ability to recover from moisture stress. Ryegrass and cocksfoot, for instance, were not very resistant to moisture stress but showed resilience by recovering. Yorkshire fog showed no resilience whereas white clover showed both resistance and resilience (Davis *et al.*1994).

However, the soil water reserves merely buffer the plant water relationships. Without precipitation stress is bound to occur sooner or later. Rainfall and its reliability is a key factor in pasture management. Figure 2 shows the pasture yield data over a seven year period from a site in Hawkes Bay (Radcliffe, 1975). The overall growth pattern shows a spring growth flush followed by low growth rates in summer with a small autumn peak. The upper and lower lines on Figure 2 are the standard deviation of the data around the mean and reflect the variability of rainfall. Note that there is a better than one in ten chance that there will be zero pasture growth during summer. This poor summer growth emphasises the importance of using fodder crops that avoid water stress better than ryegrass based pastures if lactating hinds are to be provided with high quality feed.

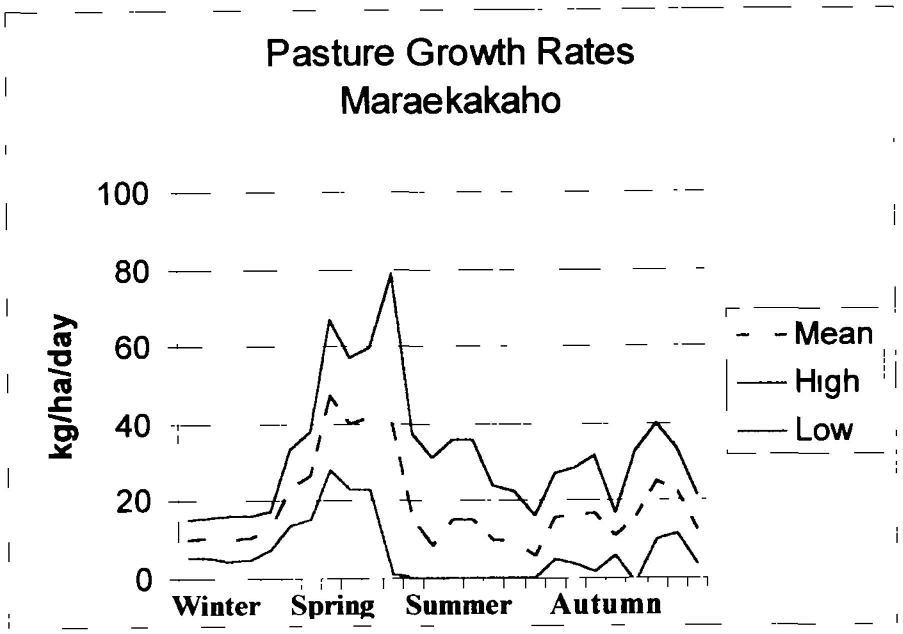

Figure 2 *Pasture growth meaned for a seven year period +/- the standard deviation for a site at Maraekakaho, Hawkes Bay (Radcliffe, 1975)*

2.3 Nitrogen

All essential nutrients need to be supplied to pasture but nitrogen is the most variable and the nutrient required in the greatest quantity. In a grass/legume pasture system the legume component can supply between 150/200 kg/ha/year of nitrogen (Steele, 1982). This fixed nitrogen returns to the system as organic matter in dung and plant litter, or as a more readily available form in urine. The organic component needs to be mineralised by soil micro-organisms before the nitrogen is available to plants. In spring, air temperatures suitable for the start of plant growth (3-5^{0} C) occur before soil temperatures permit significant mineralisation. Consequently plant growth may well be limited by nitrogen availability and the strategic use of nitrogen fertiliser will enhance early growth.

The use of nitrogen fertiliser in spring and early summer will suppress clover growth and so becomes a self-fulfilling activity; once you start using nitrogen in warmer months you have to continue because of the poor clover contribution. Nitrogen response in autumn is variable. Dry soil in summer will reduced clover growth with its nitrogen fixation and also inhibits mineralisation of any organic matter present so autumn rain will not get the growth expected. By the time sufficient nitrogen is available cool temperatures limit growth. On the other hand adequate rain during summer may allow mineralisation to proceed and the response to autumn applied nitrogen can be disappointing.

3 Quality

Returning to Figure 1, each individual growth curve has a characteristic s-shape (Figure 3 a) that is generated by three phases of growth. An initial exponential phase where the grazed sward builds up leaf area through leaf growth and tillering. Each additional leaf intercepts more radiation. There is a second linear phase where growth rate remains constant because once the canopy has closed, any additional leaves merely shade existing leaves and there is no net gain and the rate of growth is determined by the temperature and incoming radiation. Finally the growth rate tails off because the death rate of tissue equals the rate of production. This pattern of growth and senescence is called tissue turnover and while it occurs in all plants the rate of tissue turnover is especially rapid in grazing tolerant plants.

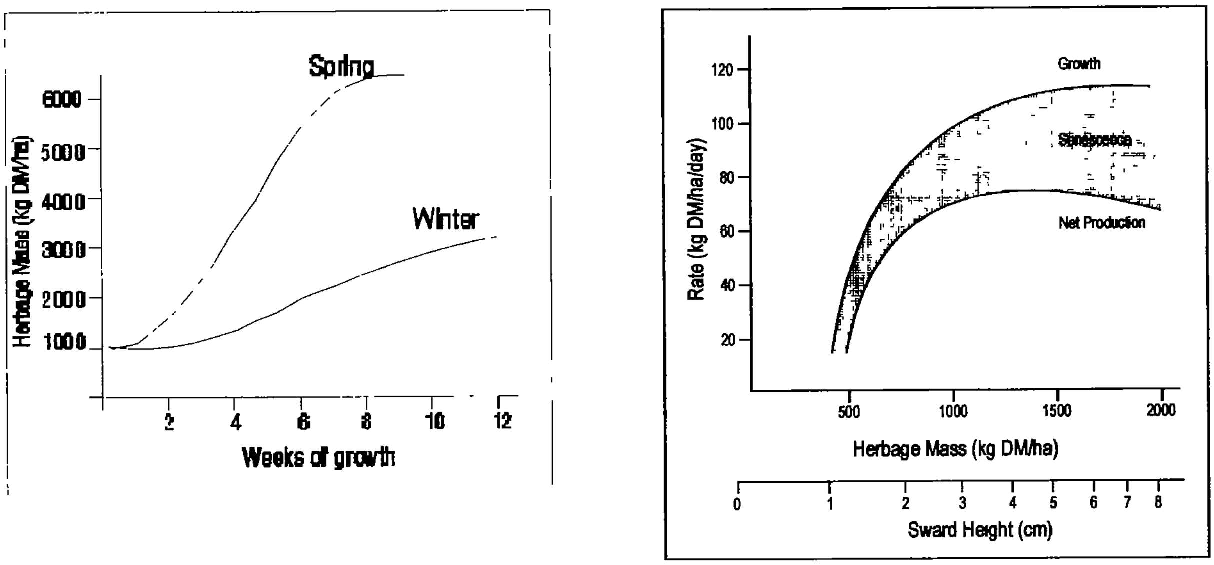

Figure 3: *(a: left) Net herbage production following grazing in a rotationally grazed sward (adapted from Brougham, 1957), (b: right) Relationship between herbage mass and leaf growth, leaf senescence, and net herbage production in continuously grazed swards (adapted from Bircham and Hodgson, 1983). Differences in herbage mass were obtained by varying stocking rate*

Tissue turnover has an impact on pasture quality. Figure 3 b shows the relationship between the growth rate of new leaves, their senescence rate and the consequent net production. Figure 3 b was achieved by continuously grazing swards to a constant height by manipulating stocking rate and is an attempt to freeze the growth pattern described in Figure 3 a. Hard grazed swards consist of predominantly young tissue and therefore of good quality but have low growth rates. Once net production reaches its maximum the senescent material reduces quality. A grazing height of 10 cm provides the best compromise between pasture quality and deer intake. In pasture species that have high tissue turnover rates there is this constant trade-off between quality and quantity.

Not all plants have high tissue turnover rates. Species that may be grouped as fodder crops accumulate dry matter in storage organs, brassicas for example, and quality remains high. However, these plants are intolerant of grazing for reasons explained in the next section. There are some species that are intermediate in that they will accumulate relatively high yields without much loss of quality and will regrow after grazing under the right conditions. This group includes lucerne, red clover and chicory, all of which provide useful forage for deer production.

4 Regrowth

Plants vary in their tolerance to grazing. Understanding the morphological and physiological attributes that affect grazing tolerance allows us to devise correct strategies for managing pastures and fodder crops. When plants grow their cells differentiate into the specialised tissues of the plants. This differentiation and specialisation usually involves the development of a rigid cell wall and sometimes the death of the cell cytoplasm. A consequence of this is that differentiated cells can not undifferentiate and resume cell division. To overcome this dilemma plants maintain centres of undifferentiated cells which are described as meristems or growing points. Tolerance to grazing is closely linked to the fate of these growing points.

4.1 Growing point survival

All higher plants grow in a modular fashion, each module comprising a length of stem, a node on that stem that subtends a leaf, and lateral growing point in the axil of that leaf. A module may also generate a root. Successive modules are produced from a terminal growing point. The lateral growing point, or bud as it is usually called, has the potential to generate new modules and become the 'terminal' growing point on a new branch. All plant shapes, from trees to ground covers, are generated from this simple basic modular arrangement.

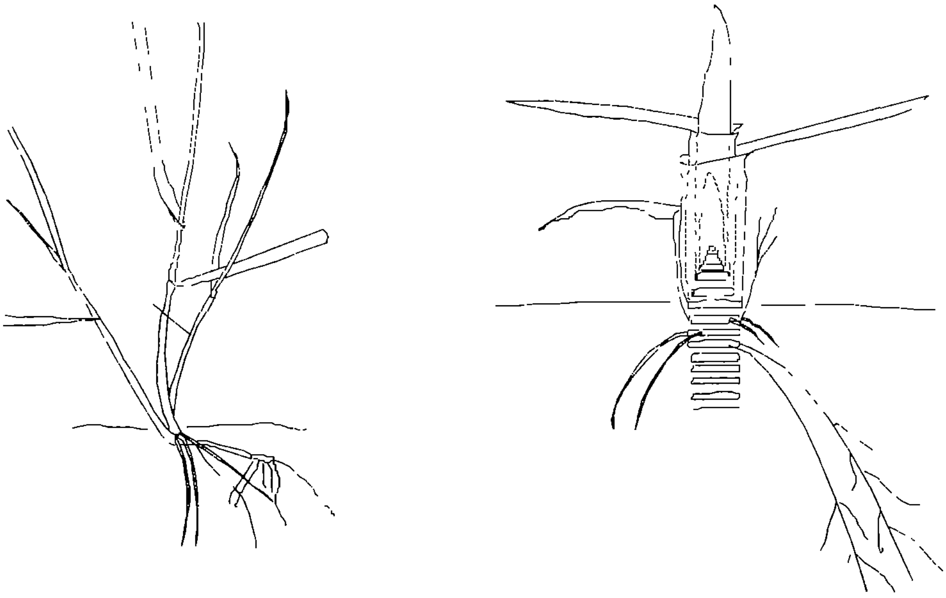

Figure 4. *Morphology of a grass tiller visible externally and schematically showing arrangement of modules and growing point. (source White and Hodgson, in press)*

Pasture grasses represent the most grazing tolerant species and this is achieved by the modules being compressed into a stem only a few millimetres high (Figure 4). This structure means that the growing point remains below the grazing height and unharmed. Furthermore, grasses grow their leaves from basal growing zones so leaf growth is not normally interrupted by defoliation. In addition the bud in the axil of each leaf has the potential to grow into a new stem, or tiller as we call it, so that the sward can thicken up. Lateral bud activity is triggered by light so open or close cropped swards with light penetrating to the base of the tillers tend to have high tiller densities whereas in tall swards the buds remain dormant. These responses can be used to thin browntop where it is becoming dominant by letting it become tall to decrease its tiller density then grazing hard. Grass stems do elongate at flowering and at that time the growing points are vulnerable. Grazing at that time will remove the growing point and put an end to the development of that tiller. The difference between annual and perennial grasses is that in perennial grasses there are replacement vegetative tillers whereas in annual grasses all the tillers go reproductive.

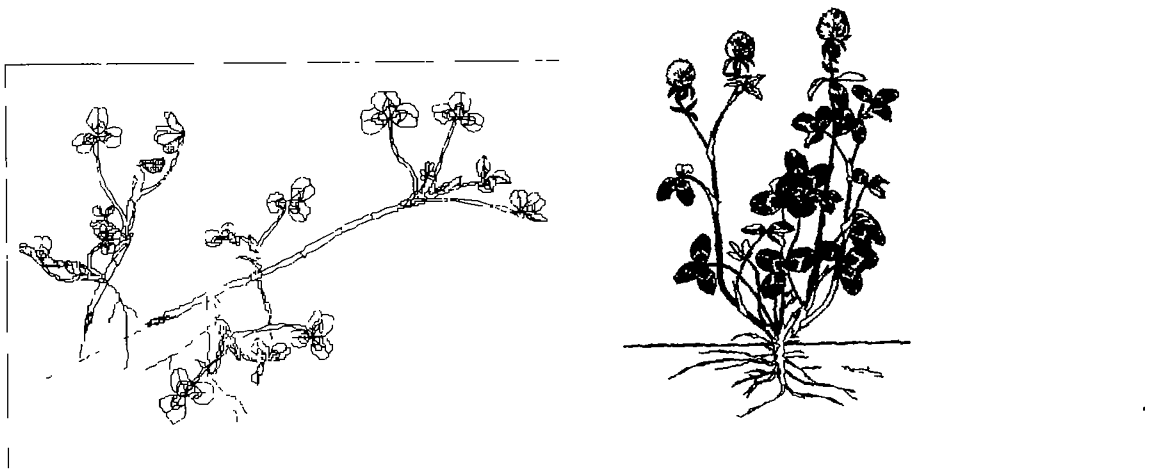

Figure 5: *Morphology of white clover (top) and red clover (bottom) showing differences in growth form and growing point location*

White clover protects its growing points by remaining prostrate (Figure 5 a). This has the additional advantage in that it can move through the sward and colonise new areas. This morphology has its disadvantages in that the petiole is the only means white clover has to get its leaf to the top of the canopy and white clovers do not persist in ungrazed situations. Leaf size and petiole length vary greatly between white clover cultivars. In contrast other legumes, like red clover (Figure 5 b) and lucerne, grow aerial branches. This allows its to be competitive with grasses and build up high yields. However, when grazed, these species lose all their active growing points which are found at the tips of the stems.

These contrasting plant growth strategies call for different grazing management strategies.

4.2 Residual leaf area

When grazed, ryegrass and white clover have the ability to start regrowth immediately. The rate of regrowth depends on residual leaf area and is related to the growth phase illustrated in Figure 3 a. Brougham (1956) measured the regrowth of a ryegrass/white clover pasture cut to three heights (Figure 6). Plots cut to 12.5 cm height immediately resumed growth at the maximum rate for the conditions while the plots cut to 2.5 cm took three weeks. The reason for this was the time taken to achieve canopy cover and full light interception. 95% light interception was achieved at 4, 12 and 20 days for the 2.5, 7.5 and 12.5 defoliation height respectively.

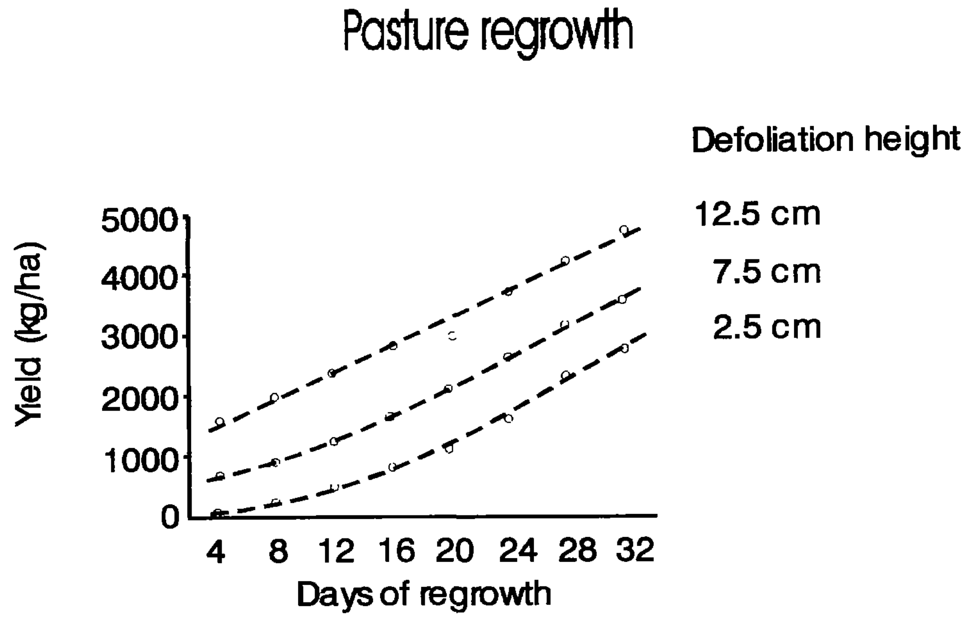

Figure 6. Regrowth of pastures defoliated to different pasture heights. Source Brougham 1956.

Plants that retain their growing points intact after defoliation are limited in regrowth rate only by rate of photosynthesis. Hard grazing may utilise available dry matter but there is a penalty in subsequent growth. In addition 5 to 10 cm has been shown to maximise sheep and cattle production (Hodgson, 1990) and deer production (Ataja, 1992). It has become something of a New Zealand trait to overgraze ryegrass/white clover pasture, relying on their remarkable resilience to persist.

4.3 Plant reserves

Plants that lose their growing points on defoliation have little option but to start their regrowth cycle from scratch. Dormant growing points resume activity from the base of the plant and generate a new branch. The energy required to do this comes from plant reserves. Plants that fall into this category include lucerne, red clover and chickory. Management strategies must include sufficient time for the plant to replace the canopy cover and to replenish reserves. These species suffer from set stocking and over grazing.

5 Persistence/weed invasion

Pasture establishment is the major cost associated with permanent pastures. The key to persistence is to maintain dense swards and deny opportunistic invaders the chance to occupy gaps. The principal threats to pasture longevity include: treading, under-grazing, over-grazing and pests.

Treading damage by stock is a real cause for concern with increasing intensification of livestock systems. Pastures are affected by soil compaction caused by high instantaneous stocking rates present in tight rotational systems. They are also vulnerable when soils are wet and the plants themselves are damaged. Ryegrass and white clover are the most tolerant of this physical damage but tussocky grasses like cocksfoot and tall fescue and species that form a crown on the soil surface, like lucerne, red clover and chicory, are particularly vulnerable. Cattle and deer have high hoof pressures and cause more damage than sheep. Also, agitated deer running around wet paddocks will severely damage pastures and crops.

Under-grazing leads to low tiller densities which on subsequent grazing leaves an open pasture. This may be due to deliberate policy, for example locking up paddocks for hay or allowing tall growth in fawning paddocks, or it may be due to losing control in good seasons with insufficient stock numbers. Overgrazing stresses plants and mortality usually leads to the presence of flat weeds.

Pests like argentine stem weevil and grass grub will very quickly eliminate susceptible species. The spread of ryegrass endophyte was facilitated by the tolerance to argentine stem weevil that it gave.

6 Summary

Permanent ryegrass/white clover pastures provide reliable and cheap fodder when environmental conditions allow. Both quality and production can be maintained if it is kept within the 5 – 10 cm height range. Strategic use of nitrogen fertiliser in early spring will enhance early growth. It is tolerant of heaving grazing and treading and, therefore, it is very persistent.

However ryegrass will not produce the abundant feed required by lactating hinds in summer and autumn. Here some specialist pasture species like red clover and chicory should be included in the farm repertoire. These species provide abundant feed in the summer/autumn period but should be allowed ample time to recover from grazing and animals kept off them in wet periods and winter.

7 References and further reading

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