Paper 1

POTATO AGRONOMY — AN OVERVIEW

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INTRODUCTION

The potato is an important world crop. In 1981 it was grown on 17.8 million hectares (FAO, 1982) and the average production was 15 tonnes/ha. The nutritive value of the potato, in terms of protein per hectare is better than any other major crop (e.g. maize, beans, peas, wheat) except soybeans (Kaldy, 1972). Although production in most developed countries has remained almost static or fallen slightly over recent years, production in a number of developing countries has risen rapidly. China and India now rank with USSR, Poland, United States and East Germany as the top six potato producing countries of the world (FAO, 1982).

In New Zealand, the area planted in potatoes has gradually fallen from 15,635 ha in 1899, to the present total of about 8,500 ha. Until about 1945, yields averaged only 12.5-15 t/ha (Claridge, 1972); average yields are now around 28 t/ha (Department of Statistics 1984). This figure includes early, seed and maincrop production; average yields of maincrop potatoes are considerably higher.

The utilisation of the New Zealand crop is approximately seed 10%, table ware 55%, processed product 30%, and export 5% (PRAC, 1985).

Potato Agronomy

Agronomy refers to the management of the physical factors which affect plant growth; factors such as seed, plant density and availability of resources necessary for growth. These factors affect initial growth, time of tuber initiation, persistence of foliage and, ultimately, the resultant crop yield and quality.

In some crops high total yield is the objective, however, more usually the portion of the crop which is marketed and its quality are more important. The relative importance of yield and quality, and the quality factors aimed for depend on the end use of the crop — whether it is destined for early lifting, seed, processing or maincrop fresh marketing. Any agronomic treatments imposed on the crop must increase the marketable component of the crop for less expense than the eventual financial return. In practise, a grower's responsibility to other crops, availability of materials and equipment, weather, and the effects of pests and diseases also determine the size and quality of the crop.

Plant growth

Conventional plant growth analysis involved measurements of leaf area and net assimilation rate (Watson, 1952). More recently, however, it has become accepted that total dry matter yield is directly proportional to the amount of light intercepted. This hypothesis was first proposed by Monteith (1977), who suggested that plant growth rates could be determined by the amount of light intercepted and the efficiency of utilization of this light. Subsequently, it has been shown that, in drought and disease free crops grown in the United Kingdom, the efficiency of utilization is not a major variable — most cultivars of a species utilize the available light with similar efficiencies (Allen and Scott, 1980). Scott & Wilcockson (1978) showed that potato crops grown with a wide range of treatments over several years, produced total dry matter yields proportional to the amount of light intercepted. This has since been confirmed by others (Khurana and McLaren, 1982). Similarly, in an Australian experiment using shading to reduce light levels dry matter yield was reduced proportionately to light received (Sale, 1973).

Although high dry matter yield is not the aim of potato growing, a number of researchers, including Ifenkwe (1975) and Allen (1977), have shown that in temperate environments tuber yield is directly related to dry matter yield under normal agronomic practises. Thus maximum tuber yield is achieved by maximizing light interception.

Maximum yield must not, however, be achieved at the expense of saleable yield. Saleable yield is mainly determined by tuber size, appearance and internal quality. Final tuber size is related to the number of tubers set (Pohjonen & Paatela, 1976). Factors affecting quality are generally less well understood (Gray & Hughes, 1978).

In the following paragraphs, the effect that a number of agronomic treatments have on the potato plant's ability to intercept light and set tubers, and on tuber quality, are examined.

SEED SOURCE

There are a number of reports indicating that the source of seed potatoes influences the resultant crop (Madec & Perennec, 1956; Broadbent *et al.*, 1961; Iritani, 1967; and Burton, 1966). Apart from the obvious effects of diseases, especially virus, most other differences can be explained by differences in physiological age of the seed. Conditions such as cooler climates, wetter soils and later planting effectively produce physiologically younger seed than from warmer climates, drier soils or earlier planting. Although there may be slight differences in performance of seed not directly attributable to physiological age, isolation of other causative factors by experiment would be difficult because of their smallness.

SEED QUALITY

The advent of a potato certification scheme in New Zealand in 1927 did much to improve seed quality by rejecting inferior lines e.g., the best Epicure line yielded 24 t/ha while the worst yielded only 8t/ha (Claridge, 1930). The recent release of pathogen tested seed has further boosted the quality of seed potatoes (Ovenden and Martin, 1981; Ovenden *et al.,* 1985).

SEED TREATMENTS

Various chemical and hormonal treatments have been applied to seed for various purposes.

Dormancy breaking — many chemicals have been reputed to break dormancy (Genet & Bedi, 1976), those used commonly include gibberellic acid, ethylene chlorhydrin and thiourea, or combinations of these. Low temperature storage prior to conversion to sprouting temperatures (Wurr & Allen, 1976) may also stimulate dormancy break.

Crop growth — dipping seed tubers in a number of compounds has been reputed to improve crop growth, however it has not become widely used overseas or in New Zealand. It has been shown that the use of gibberellic acid is a means of increasing stem number and the resultant tuber set in Rua (Genet, 1978). Disease prevention — various fungicides (e.g. benlate and thiabendazole) are used to protect tubers against pathogens. (See paper 3).

SEED SIZE

As the size of the seed tuber increases, the potential number of stems increases. Manipulation of seed tuber size is one possible way of affecting plant density and is dealt with under that heading.

PHYSIOLOGICAL AGE OF SEED

The conditions under which seed is stored between harvest and planting have a marked effect on the subsequent development of the plant. How the seed is stored determines the physiological age of the tuber, which is known to affect subsequent growth and yield of the crop (Toosey, 1964).

Typically, seed is dormant at harvest and, depending on the variety, remains so for some time. Once dormancy is over sprouts can begin to grow if temperatures are high enough (usually above 4°C). The storage temperature determines the rate at which sprouts grow.

Although the term physiological age and its affect on subsequent growth have been known since 1955 (Madec & Perennec, 1955), its usefulness was not initially exploited because there was no method of measuring it. Allen *et al* (1979) noted that lengthening the sprouting period and increasing the storage temperature both hastened sprout growth, and considered that measurement of a combination of these two factors may provide a satisfactory indicator of physiological age. Initial experiments showed a good relationship between physiological age, measured as day degrees greater than 0°C during sprout growth, and resultant crop growth and yield.

In a number of experiments conducted between 1973 and 1981 O'Brien *et al.* (1983) examined the effect of physiological age on sprout development and field growth of two early potato cultivars. They found that increasing the age of seed tubers resulted in earlier emergence and tuber initiation, larger early leaf areas and increased early tuber yields. As growth proceeded young seed produced the greatest and most persistent leaf areas and yields surpassed those of older seed. In these experiments, the measure of physiological age used was the number of day degrees above 4°C from the end of dormancy.

In Great Britain, a large proportion of seed tubers are presprouted or physiologically aged — all early plantings and 25% of maincrop plantings (Potato Marketing Board, 1968a and 1968b). In New Zealand, apart from by home gardeners, little presprouting is conducted. In studies with Rua, a late maturing cultivar, the effect of two presprouting regimes compared to unsprouted seed has been studied (Genet, 1977). Sprouted seed emerged earlier and at harvests after 76 days and 106 days yielded significantly better, however there were no significant differences after the final harvest 150 days from planting. As this trial could have been planted 40 days earlier and Rua is a very late cultivar, it is doubtful whether the advantages of presprouting would be economic under New Zealand conditions for maincrop potatoes. In a trial (Genet, unpublished) with Ilam Hardy and Arran Banner harvested after 102 days, presprouted seed emerged earlier and, although significantly less tubers were produced, a significantly greater weight of marketable size potatoes resulted. Thus presprouting may be advantageous in early harvested crops in Canterbury, but where crops can be planted almost all year round (Pukekohe), the better early growth resulting from presprouting may be less important. However, Genet (1983) showed that with shy-sprouting cultivars like Rua, planting dormant seed, particularly in cool damp conditions, can result in poor emergence.

PLANTING

Time of planting

Climate dictates when planting can take place, and the cultivar and desired harvest date determine when planting should occur. In cultivars which maintain foliage for a long time, early planting may be an advantage, however for earlier maturing cultivars early leaf cover in spring may be at the expense of autumn cover.

It appears that early planting in milder climates allows earlier leaf growth and higher ultimate yield (Allen, 1977), whereas in cooler climates early growth is restricted until temperatures rise (Bremner & Radley, 1966).

Soils

Potatoes grow best in light soils as long as the water supply (rainfall or irrigation) is adequate. Open soils allow an unrestricted growth, while heavy clay soils can cause distorted tubers (Claridge, 1972). Soils should be free draining as potatoes cannot stand water logging, and rot if submerged for more than 24 hours.

Ridging

The effect of ridging, and the size, shape and time of building can affect the saleable yield of potatoes. Ridge shape affects soil temperatures, moisture content and soil covering of the tubers (Kauwenhoven, 1978). In New Zealand, ridges may be formed at planting or built up later, after crop emergence. Either method is adequate, however good ridges are essential to prevent tubers becoming exposed to light and turning green, and to reduce damage caused by tuber moth. This is particularly important where the crop is to be irrigated as soil may be washed off the ridge.

Rotation

Although crop rotation has long been promoted as necessary for good crop husbandry, many examples of successful potato growing under monoculture exist in New Zealand, notably in Opiki and Pukekohe. The discovery of PCN and the ensuing regulations imposed on infested properties (Anon, 1970) have led to less continuous cropping. Potatoes grown for certified seed must not be planted within three harvest seasons of a previous potato crop (Cleverly, 1984).

PLANT DENSITY

Manipulating plant population can affect the amount of light the crop intercepts and the size proportions of the resulting tubers produced. In general, tubers for seed should be small, tubers for table use and crisping medium sized and tubers for french fries large.

Although single seed tubers are planted at regular intervals down a row, each tuber produces a number of stems, which eventually grow as individual plants. It is now accepted that stem density rather than number of hills or roots should be used to describe plant population or density (Wurr & Grey, 1973).

Stem density can be changed by altering the row to row spacing, within row spacing and the size of seed planted. In recent years there has been a trend towards increasing row widths. Wider rows allow more soil to be drawn over the developing tubers to prevent greening. Plant to plant spacing varies depending on the cultivar, the physiological age and size of the seed tuber, and the size of tubers required at harvest. A number of experiments have defined the appropriate stem densities required to give optimum tuber yields in Great Britain (e.g. Sharpe & Dent, 1968; Wurr, 1974). There has been virtually no work conducted on stem density in New Zealand, except for Wilson (unpubl.) who found that 20 stems/m² gave highest saleable yields of Ilam Hardy at early lifting in Pukekohe.

FERTILIZERS

Fertilizers and irrigation applications are the two agronomic factors which affect tuber quality the most. The potato crop accumulates large quantities of nitrogen (N) and potassium (K), and somewhat smaller quantities of phosphate (P) (Table 1). The inherent soil fertility and type of crop grown determine the type and rate of fertilizer used

Table 1: The nutrients removed in tubers (kg/ha) and yield in five separate experiments (from Ezeta and McCollum, 1972).

Location		Peru	Utah	Maine	North Carolina	England
Cultivar		Renacimient	Russet Burbank	Green Mountain	Pungo	Craigs Royal
Nutrients removed	N	80	107	107	100	147
in tubers	P	16	11	11	16	22
kg/ha	K	230	107	107	131	220
Total dry matter production t/ha		12.6	9.9	7.9	7.5	12.7
Tuber dry matter/total dry matter		0.70	0.77	0.75	0.83	0.96

on potatoes in New Zealand. Some varietal differences in response have been reported in New Zealand by Mountier & Lucas (1981) and G. Wilson (pers. comm).

Recommendations for early potatoes grown at Pukekohe are for high levels of fertilizer; 2.5 t/ha of 13:9:8, plus a sidedressing of 325 kg of urea (Wood, 1981). Main crop potatoes at Pukekohe should receive similar high levels of base fertilizer, however, side dressings of N are not normally applied. In Canterbury, much lower rates are recommended, 375 kg/ha of superphosphate after good pasture, or 625 kg/ha of compound potato fertilizer after a depletive crop (Jamieson & Genet, 1981). Soil pH should be between 5.0 and 5.8.

Nitrogen is the element most likely to affect growth in potato crops (Gunasena and Harris, 1968 and 1971). Applications of nitrogen have been shown to delay tuber initiation (Ivans and Bremner, 1965), increase leaf area and duration (Dyson and Watson, 1971), and increase yield (Painter and Augustine, 1976). High nitrogen levels can also promote rapid haulm growth with resultant hollow heart of tubers (Crumbly *et al.,* 1973) and can increase susceptability to blackspot bruising. Potassium tends to alleviate black spot bruising (Hughes *et al.,* 1975); this has been confirmed in New Zealand by Flint (pers. comm) however his work shows that significant effects will only be achieved if initial soil levels are low. Both nitrogen and potassium tend to reduce dry matter content (Kunkel and Holstaf, 1972), with the chloride salt having a more depressing effect than sulphate (Dickens *et al.,* 1962). In boiled potatoes high N:K ratios tend to increase after-cooking darkening (Hughes and Mapson, 1967), however Genet (unpublished) in New Zealand was unable to control levels of after-cooking darkening by altering levels and combinations of nitrogen and potassium in the field.

Thus, although large quantities of both nitrogen and potassium are removed from the soil, care is required in reapplying them as high levels, particularly of nitrogen, can have detrimental effects on tuber quality.

WEED CONTROL

Weeds are important as they compete for resources with the potato crop. They reduce light interception by shading, and utilise fertilizers and water at the potato's expense.

Traditionally, mechanical methods — harrowing down, interrow cultivation and moulding up — are used in Canterbury, with increased use of herbicide further north (Wilson, 1976). The most common herbicides used in New Zealand for potatoes are preplant (eptam), pre-emergence (linuron, gesagard, paraquat) or post-emergence (metribuzin), or combinations of these chemicals.

Cox (1967) presented results of weed control and potato tolerance to the main triazine and urea derived herbicides (linuron, monolinuron, metrobromuron, prometryne and ametryne). He found all five materials applied as pre-emergence sprays controlled weeds but at the higher rate (1 kg/ha) monolinuron caused yield loss. Very good weed control in potatoes with metribuzin was recorded by Wilson (1974) at Pukekohe and Cox (1974) at Levin.

IRRIGATION AND PEST AND DISEASE CONTROL

Water supply can have a dramatic effect on the yield and quality of potatoes. Water shortages reduce dry matter production directly by lowering the rate of photosynthesis, limit leaf growth and therefore indirectly the production of dry matter, and hasten crop senescence. Uneven water supplies cause secondary growth which adversely affects tuber quality. Pests and diseases similarly affect plant growth and ultimate yield as well as reducing tuber quality. These topics are dealt with in more detail in later chapters of this publication.

POTENTIAL YIELDS

In 1975, Evans produced a blueprint for maximising potato yields in Great Britain. The major requirements for maximum yield included larger seed size, increased fertilizer and seed rate, blight and aphid sprays and irrigation, the aim being to ensure that nothing limited crop growth. Tuber yields of 80 t/ha were predicted but not always achieved (Evan, 1978). Allen and Scott (1980) suggest however, that very high yields may be produced without significantly raising inputs, and trials by Allen (1977) and Ifenkwe (1975) tend to support this view. Establishment of a full canopy of leaves as early as possible and maintaining this as long as possible to allow maximum light interception should be the objective of growers seeking high yielding crops.

Allen and Scott (1980) have calculated that crops with tuber yields of 105 t/ha at 22% dry matter or 115 t/ha at 20% dry matter could be grown with normal radiation levels at Sutton Bonnington in England, and that even higher yields would be possible nearer the coast where light intensities are higher. Van de Zagg & Burton (1978), using data from Sibma (1970), calculated tuber yield of 100 t/ha in the Netherlands, O'Keefe *et al.* (1982) obtained 88 t/ha in Nebraska, USA.

In New Zealand, Mountier and Lucas (1981) produced tuber yields of more than 80 t/ha with Ilam Hardy and in trials at Crop Research Division, Lincoln, using pathogen tested seed, Rua produced 90 t/ha, Ilam Hardy 73 t/ha, Sebago 81 t/ha and Iwa 104 t/ha (Ovenden, pers.comm). Anderson (pers. comm) produced over 150 t/ha with a *S. tuberosum x* Neotuberosum line at Pukekohe in small plot trials.

Using average radiation figures for Canterbury, tuber yields of 100 t/ha should be possible. In a season the crop should intercept 2691 MJ/m^2 (Table 2). Assuming 50% photosynthetically active radiation, a harvest index of 0.8 and production of 2.0 g of dry matter per MJ of photosynthetically active radiation, then tuber yields of 107 t/ha at 20% dry matter could be achieved. In New Zealand,

Table 2: Light interception for Canterbury with onset of leaf growth on 1st October.

Month	% light intercepted (MJ/m²)	Incident radiation (MJ/m²)	Intercepted radiation
October 1st half	10	) 494	25
2nd half	25	)	63
November 1st half	50	) 594	150
2nd half	75	)	225
December	100	662	662
January	100	641	641
February	100	514	514
March	100	414	414
Total			2,694

a 50 t/ha crop is considered very good; there is still room for improvement.

QUALITY

The saleable crop consists of potatoes of suitable size, appearance and internal quality.

Factors controlling tuber size are now reasonably well understood, however factors affecting tuber appearance and internal quality are generally not so well understood (Gray and Hughes 1978). Acceptable tuber size depends on the end of use of the potatoes — large potatoes are usually required for french fry production, medium sized tubers for crisp manufacture and prepacking, and small tubers for seed.

Appearance factors which affect the saleability of potatoes including greening, shape, growth cracking, second growth, harvest damage and the effects of pests and disease. The importance of the internal quality of the tuber depends on its end use, however all potatoes grown for human consumption should be free from fleck, hollow heart and other similar defects. Such physiological disorders are poorly understood, however, hollow heart, fleck and growth cracking usually result after excessively rapid tuber growth, and second growth usually results when plant growth recommences after a period of slow growth caused by high temperatures and drought. Agronomic practises such as regular, adequate water, which encourage an even growth rate should help reduce the incidence of these disorders.

Potatoes destined for processing should have high dry matter and low reducing sugar content. High dry matter is usually associated with well managed crops, harvested at maturity. Irrigation should be withheld towards the end of the growing period for best results (Talburt and Smith, 1975). Reducing sugar content is mainly influenced by storage temperatures. Dry matter and reducing sugar content also vary from cultivar to cultivar.

The main factors involved in the boiling or steaming quality of potatoes are after-cooking darkening, sloughing, stem-end blackening, texture and flavour. These factors are cultivar dependent but environmental factors are also involved.

SUMMARY

The potato grower's aim is to produce a high yield of saleable potatoes. Maximum interception of light ensures maximum dry matter accumulation. The grower should plant quality seed in free draining, fertile soil, and provide good ridges to protect tubers from greening and tuber moth. Fertilizers should be balanced and water made available as required so the plants grow at an even rate. Pests and diseases should be watched for, and preventative measures taken so they do not reduce leaf area or damage tubers.

Recent information on agronomic requirements of potato crops in New Zealand is fairly limited and thus reference to overseas work has had to be made in this article. Specific areas requiring more local information include use of seed of different physiological ages, and appropriate fertilizer rates and plant densities particularly as they relate to the production of potatoes for specific end uses, such as boiling, french fry or crisp manufacture.

New cultivars require agronomic evaluation to obtain the best possible results.

Not all this information can or needs to be provided by research scientists. Growers should be experimenting themselves, to obtain the best results for their particular situation. Yields of 100 t/ha are theoretically possible and have been achieved in small plots in New Zealand. This offers a challenge to growers to monitor their crops and try and achieve high yields of quality produce.

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