A MAF Sustainable Farming Fund Project to improve pea production and sustainability.

The Pea Industry Development Group (PIDG) was established to improve pea yields and sustainability of the Industry in New Zealand. The PIDG represents all components of the New Zealand pea industries. This includes farmers growing peas for processing, seed and grain, their levy agencies, pea processing companies, seed and grain companies, the agrichemical industry and research providers. This group was constituted to highlight priorities for improving productivity of pea growing as a component of arable farming in New Zealand.

The project partners are:

FAR

Plant Research (NZ) Ltd

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CANTERBURY SEED COMPANY LIMITED

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Te Manatū Ahuwhenua, Ngāherehere

Horticulture New Zealand

PGG Wrightson Seeds

CROP & FOOD RESEARCH
Mana Kai Rangahau

Bayer CropScience

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Making Peas Pay

PEA INDUSTRY DEVELOPMENT GROUP

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Pea Industry Development Group
Foundation for Arable Research
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BACKGROUND

The Pea Industry Development Group (PIDG) was formed in 2002 to address the issue of poor profitability and the decline in interest of farmers to grow peas. Peas are a very important crop to growers as they provide a valuable spring sown break crop which supplies product for processing, seed, food and feed uses. The group was formed with the objective of identifying some of the key constraints to growing a profitable pea crop and delivering information to overcome these constraints to growers. The group is comprised of farmers, processors, seed companies, industry bodies and researchers and all parties have agreed to co-invest in a research and extension plan to deliver benefits to the industry.

The parties are: Bayer Crop Science, Canterbury Seed Company Ltd, Cates Grain and Seed Ltd, Foundation for Arable Research, Heinz-Watties Ltd, Horticulture New Zealand, MAF Sustainable Farming Fund, McCain Foods Ltd, Midlands Seed Ltd, New Zealand Institute for Crop & Food Research Ltd, Plant Research (NZ) Ltd, PGG Wrightson Seeds Ltd, Seed Production (NZ) Ltd and Seminis.

The PIDG has invested in an R&D programme over the last six years, with support from MAF Sustainable Farming Fund. Throughout the project there have been a number of field days, seminars and FAR Arable Updates which have reported outcomes from the project. This publication is intended to combine information collected through the project, plus a significant amount of previous research data and crop management information into a document providing information to farmers and industry that will result in the production of high yields of high quality peas. The guide is easy to follow and has a number of photos and figures designed to help readers easily understand the key points and messages.

Nick Pyke
Project Manager

PEA CHARACTERISTICS

Process

Common name	Process peas, vegetable peas, edible podded peas
Grain characteristics	Wrinkled green cotyledoned grain with a clear – green seed coat.
Maturity range	Early (9 nodes to first flower) to 17 nodes.
Leaf characteristic	Mix of leafed and semi-leafless varieties available.
Typical sowing window	Large range from late July through to early December.
Typical end use	Freezing, dehydration, canning, fresh vegetable sold as unthreshed pods, low fibre and large podded varieties (eg snow peas) consumed frozen and fresh.
Domestic and/ or export	Mix of export and domestic use.
Organic production possible?	Yes.
Major varieties	Ashton, Bolero, CFR Sonata, CFR Pinacle.

Green/blue

Common name	Green/blue field peas
Grain characteristics	Smooth/spherical blue-green cotyledoned grain with a transparent seed coat.
Maturity range	Usually mid-season, flowering around 15-17 nodes.
Leaf characteristic	Almost exclusively semi-leafless plant types.
Typical sowing window	September to end of October.
Typical end use	Split peas for soup, canning, whole seed and extruded snack production, rolling.
Domestic and/ or export	Majority exported for food use.
Organic production possible?	Yes.
Major varieties	Aragorn, Ariel, Crusader, Prussian Blue.

White/yellow

Common name	White/yellow field peas
Grain characteristics	Smooth – slightly wrinkled yellow cotyledoned grain with a transparent seed coat.
Maturity range	Mid-season maturity with node to first flower from 15-17 nodes.
Leaf characteristic	Apart from Komet, all are semi-leafless.
Typical sowing window	September to end of October.
Typical end use	Food use for split peas for soup, canning, extruded snack products, pea flour, animal feed.
Domestic and/ or export	Majority are exported.
Organic production possible?	Yes.
Major varieties	Alezan, Komet, Miami, Santana.

Maple

Common name	Maple field peas
Grain characteristics	Irregular/dimpled brown mottled grain with a yellow cotyledon.
Maturity range	Mid-late maturity with first flowering node usually from 16-18 nodes.
Leaf characteristic	Both tall indeterminate varieties (eg Whero) and shorter, more determinate forms (eg Courier).
Typical sowing window	August to end of October.
Typical end use	Predominantly used for bird feed industry. Undesirable for animal feed due to high tannin and anti-nutritional compounds such as trypsin inhibitor. Used also for food sprouts.
Domestic and/ or export	Almost exclusively exported.
Organic production possible?	Yes.
Major varieties	Courier, Whero.

Marrowfat

Common name	Marrowfat field peas
Grain characteristics	Large, irregular, grain with green cotyledon and clear seed coat.
Maturity range	Mid season maturity with first flower around 15-16 nodes.
Leaf characteristic	Generally marrowfat varieties are short and leafed although new semi-leafless varieties are becoming popular.
Typical sowing window	September to end of October.
Typical end use	Food use in high value snack production in Japan and S.E. Asia. Premiums are paid for high quality colour, and uniform large grain.
Domestic and/ or export	Almost exclusively exported.
Organic production possible?	Yes.
Major varieties	Midichi, Midlea, Primo.

Forage

Common name	Forage peas
Grain characteristics	Medium sized tan/ brown or green coloured grain with a yellow or green cotyledon.
Maturity range	Usually late and indeterminate maturity to synchronise with cereal maturity.
Leaf characteristic	Both leafed and semi-leafless varieties available. Varieties are tall and highly productive in relation to dry matter with a low grain harvest index.
Typical sowing window	May to end of October.
Typical end use	Forage use: can be grown as a stand alone forage or silage crop or in combinations with cereals.
Domestic and/ or export	Domestic use.
Organic production possible?	Yes.
Major varieties	AP2, Magnus, Provider.

The choice of cultivar is based on a combination of agronomy and eating quality. A range of cultivars will often be used by a processor and seed company to provide each grower with best choice of genetics to:

- match particular soil type and local climate;
- match sowing date;
- protect against disease threat;
- address weed issues;
- handle moisture stress and
- mature earlier or later than other crops planted at a similar time.

CROP ROTATION

KEY POINTS

- Peas are considered as a restorative crop in an arable farm crop rotation.
- As a spring sown crop they will often follow a winter green feed after a cereal or as a second break crop after grass seed. Generally peas will be used as a break crop before sowing winter wheat.
- In process crop rotations, early pea crops may be followed by sweetcorn.
- Break crops are used to provide weed control options, disease and pest breaks, improve soil structure, improve fertility (fix N) and reduce water use. Peas can be used for any or all of these purposes.

INFLUENCE OF PEAS ON DISEASE INCIDENCE

A FAR, MAF SFF funded project examined the influence of peas (and other break crops) on the incidence of take-all in wheat crops. Two crop rotation trials compared different preceding crops on levels of take-all in the following first and second wheats. In the first wheat rotation there were two main findings:

- First wheats following barley had higher take-all severity than first wheats preceded by linseed, spring brassica, peas or pasture.
- First wheats following a pasture had an intermediate take-all severity between barley and peas, indicating that pasture species or pasture weeds may not be as good as other break crops from take-all hosts.

For the second wheat rotations (comparing second wheats following barley, linseed, spring brassica, peas or pasture) levels of take-all did not differ between any of the rotations. This result confirmed the findings of a field survey in the 05-06 season where there was no clear effect on take-all levels of crop type preceding second wheats.

YIELDS AND PROFITABILITY OF PEAS AS A BREAK CROP

A FAR/MAF SFF funded project on crop sequences examined the yields and gross margins for the break crop and the subsequent first and second cereal crop (FAR Arable Extra No. 68). The data presented is the mean for two time replicates commencing a year apart.

Table 1. Break crop yields (t/ha) and following first and second wheat yields (t/ha). Mean of Time rep 1 (2003-2006) and Time rep 2 (2004-2007).

Break Crop Sow Year	Break Crop Mean 2003 & 2004 Yield (t/ha)	1st Wheat Mean 2004 & 2005 Yield (t/ha)	2nd Wheat Mean 2005 &2006 Yield (t/ha)
Linseed	4.0	10.9	5.8
Brassica 1	1.04	11.0	6.0
Barley	10.8	8.0	6.4
Peas	4.4	10.7	5.7
2-yr Ryegrass	(topped)	10.1	6.4

To quantify the economic benefits of peas in a rotation, ideally the entire crop rotation must be considered. The isolated comparison of crop gross margins does not reveal the monetary value of peas to the following crop. Higher yields for the following crop, cost savings due to nitrogen fixation and reduced tillage due to improved soil structure, as well as a better management of labour are some of the advantages of peas. Some European crop model calculations of rotation gross margins demonstrate that diversifying tight cereal rotations (75% or more cereals) with peas does not cause a drop in farmers' income. On the contrary in most cases the pea rotation offers slightly higher gross margins than tight rotations.

The following is using the yield data from the crop sequence trial in Table 1 and using gross margins based on approximate crop values in 2008. This table does not reflect reduced fertiliser usage due to the N neutral status of peas or the potential to reduce crop establishment costs following peas.

Table 2. Crop individual gross margins and cumulative gross margin. Mean of Time rep 1 (2003-2006) and Time rep 2 (2004-2007)

Break Crop Sow Year	Break Crop Mean 2003 & 2004. $ Gross margin/ha	1st Wheat Mean 2004 & 2005. $ Gross margin/ha	2nd Wheat Mean 2005 & 2006. $ Gross margin/ha	Cumulative $ Gross margin/ ha for break crop and two wheat crops
Linseed	2480	5123	2726	10329
Brassica 1	4864	5170	2820	12854
Barley	4428	3760	3008	11196
Peas	4400	5029	2679	12108
2-yr Ryegrass	(topped)	4747	3008	n/a

Crop values - Linseed $620/t, Brassica $4.66/kg, Barley $410/t, Peas (garden) $1000/t, Wheat $470/t.

HERBICIDES

Care needs to be taken in planning crop rotations to avoid using herbicides in previous crops that have a long soil residual period and can cause damage to peas.

APHANOMYCES AND PEAS

KEY POINTS

- Aphanomyces can markedly reduce the yield of peas.
- Conduct Aphanomyces soil tests to ensure ground is fit for growing peas.
- Avoid growing peas in ground that has hosted peas in the previous 4-5 years as spores can survive in the soil for long periods of time.

DISEASE SYMPTOMS AND OCCURRENCE

Aphanomyces root rot is a major disease in peas in New Zealand and elsewhere in the world. Above ground plant symptoms are stunting, yellowing of leaves, necrosis and plant death. Root symptoms are water soaked necrosis of roots, root die back and reduced root development. The disease is spread from soil borne spores within paddocks and these very resilient spores can survive for long periods (in excess of five years) in the soil in the absence of susceptible crops. The host range of this pathogen includes peas, beans, alfalfa, red clover, white clover and some leguminous weeds. Some non-leguminous hosts include spinach, field pansy, chickweed and shepherd's purse. The pathogen can attack and infect peas at any growth stage, but infection generally occurs soon after emergence in heavily infested fields during wet weather. It is recommended that peas are not planted in ground that has hosted peas within the previous 4-5 years. Testing for the disease will give growers a guide as to the risk of Aphanomyces in the soil and will reduce the risk of crop failure due to root rot.

IMPACT ON YIELD

Aphanomyces has been reported to significantly influence pea yields. In severe cases peas will produce no seed while in less severe cases seed numbers and seed size can be reduced. PIDG crop monitoring studies in 2005/06 and 2006/07 (Joint Industry Update No. 10) have shown that a reduced yield may be expected, with an increased disease severity index (the measure of Aphanomyces risk). This is illustrated in Figure 1.

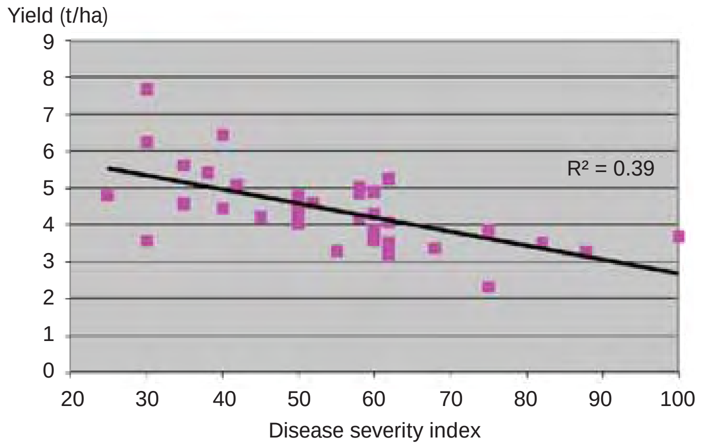


Figure 1. Correlation between Aphanomyces root disease observed in the field and pea yields in marrowfat peas 2005/06 (n=33)

APHANOMYCES SOIL TESTING

Prior to planting, it is advisable to get an Aphanomyces test done on the soil from the paddock that you plan to plant into peas. The test involves taking a soil sample from the paddock. It is important to collect a representative sample of soil from the paddock. Using a soil sampler take cores at regular intervals while walking a W line across the paddock. Collect and mix thoroughly and send 5-7kg to the lab for testing. Seeds are grown out in the soil in the glasshouse. The plants are then scored for disease and the plant scores are used to calculate the Disease Severity Index (DSI) of the paddock. The plants are scored on a scale of 0-4, with 0 being the best and 4 the worst, Figure 1 illustrates the scoring scale. Three categories of paddocks can be distinguished on the basis of DSI; paddocks with DSI of 0-50 can be safely planted with peas; 51-69 of questionable safety and 70-100 should not be planted with peas. Aphanomyces soil tests usually take 4-6 weeks to complete, therefore it is important to get the tests done well in advance of the planting date. For more information on Aphanomyces soil tests contact your seed company representative.

Figure 2. Pea plants from the disease severity index method for root rot potential showing from left to right, appearance of roots in disease classes 0, 1, 2, 3 and 4 respectively.

SOIL PROPERTIES

KEY POINTS

- Soil compaction can restrict root growth and development in peas.
- Compaction can result from uncontrolled trafficking during establishment and harvesting of peas and other crops, particularly under wet conditions.
- Soil organic matter helps to maintain good soil structure and topsoil fertility.
- Good aggregation of soils is important to maintaining adequate infiltration of water, air and nutrients into the soil profile and promoting optimum root development.

SOIL QUALITY UNDER PEA CROPS

Soil quality is defined as the fitness of soils for a particular use, in this case the production of arable and process vegetable crops. The quality of soils used for pea production in Canterbury was evaluated as part of the Pea Industry Development Group's (PIDG) project entitled Improved Pea Production for Sustainable Arable Farming. A total of 33 paddocks sown to marrowfat peas were selected for monitoring in this project. Of these, 29 paddocks were sown to the marrowfat cultivar Midichi and these are the basis of the soil quality results reported below. The soils on these paddocks ranged from light stony silt loams to heavy deep clays, and they had a wide range of chemical and physical characteristics. The soil indicators measured in this study; the mean, maximum and minimum values obtained across the 29 paddocks and the percentage of paddocks with values that fall with the optimum range for each indicator are shown in Table 3.

The results of soil monitoring work showed that soil chemical fertility was less than optimal for some of the paddocks monitored under pea production but there was no clear evidence that these fertility conditions limited pea crop performance in this study.

Although nearly 41% of the paddocks monitored had soil pH values below the optimum range, most of the measured values were no more than 0.1-0.2 pH units below the optimum range. These low pH conditions are easily rectified with additions of lime. Olsen P levels were also below the optimum range in 38% of the paddocks monitored. While most pea crops do not benefit from increased P fertility, maintaining Olsen P levels between 10 and 35 is recommended for most other arable crops and would therefore reduce the risk that P is limiting to subsequent crops in the rotation. Whereas between 3 and 93% of the paddocks had cation (Ca, Mg, Na, K) levels that fell outside the optimum range, in most of these cases the measured values exceed the optimum range, so there is no evidence that these fertility test levels limited crop performance in this study.

About 55% of the paddocks had total C and N levels that were outside the optimum range. While it is difficult to quantify a direct effect of total soil C and N on crop performance, it is known that they reflect the soil organic matter level. Furthermore, soil organic matter plays an important role in enhancing soil structural stability, water holding capacity and biological activity, all of which may affect crop performance. Aggregate stability (MWD or % > 1mm) is a measure of the soil's ability to resist breakdown when dry soil is rapidly wetted, which can cause surface ponding and the formation of crusts. In this study less than 22% of the paddocks had values below the optimum range.

Many paddocks had poor soil structure (e.g. low structural condition scores) and at least 50% showed some evidence of soil compaction (e.g. high bulk density, high penetration resistance). The greatest areas of concern were with aggregates <0.85mm, structural condition scores and penetration resistance in the top soil (0-15cm). The tendency for a high proportion of monitored paddocks to have low structural condition scores and a high percentage of <0.85mm aggregates is consistent with poor aggregation of the top soil. These conditions can increase the risk of erosion and restrict the movement of air, water and nutrients into the soil profile. Soils composed of lots of very small soil aggregates are also prone to surface capping, which can reduce crop emergence. Aggregates <0.85mm in diameter also have a relatively high risk of erosion by wind or water. Soils with lots of very large aggregates in the surface (0-10cm) tend to have very low structural condition scores. These low scores are usually associated with a breakdown in soil structure that results in the formation of large dense clods or with topsoil compaction that is associated with excessive wheel trafficking or livestock treading. These large dense aggregates can restrict root growth and development and limit the water and nutrient storage capacity of soils.

A high proportion of the paddocks (52%) also had high penetration resistance values, indicating that topsoil compaction may be a factor limiting crop performance in some cases. Bulk density is another indicator of soil compaction. Only about 30% of the paddocks monitored had topsoil (0-15mm) bulk density values that exceeded the optimum range; however more than 50% of the paddocks had subsurface (15-30cm) bulk density values that exceeded the optimum range. Results of the pea crop monitoring project in 2006 showed that pea yields tended to decrease with increasing bulk density. On average, penetration resistance at the 15-30cm depth was also very high, although the optimum range for penetration resistance at this depth is not known. Where topsoil compaction is an issue, targeted cultivation can help to create a finer tilth by breaking down large dense clods. However without improving organic matter levels this is only likely to be a short term solution and topsoil compaction will often return. Where the compaction is concentrated at or below the depth of cultivation (e.g. tillage pans or deep wheel marks), subsoiling or ripping can markedly improve root penetration and water drainage. However care should be taken to first confirm that compaction is restricting root development (i.e. dig a hole, have a look) before applying these practices. It is also important to target the ripping to the affected soil layer. Subsoiling or ripping at an incorrect depth or under wet conditions can worsen the problem.

Overall, the best ways to reverse soil compaction and improve soil structure in the longer-term are to: practice controlled trafficking; avoid driving on ground under wet conditions; return crop residues wherever practical; apply non-inversion minimum tillage practices and sow and maintain grass pastures or grain crops with large fine root systems.

EFFECTS OF MANAGEMENT ON SOIL QUALITY

For many crops, the tilth of the seedbed is important to achieving good crop establishment. Seedbed tilth can be defined by the size distribution of soil aggregates. Unfortunately the optimum aggregate size distribution for pea establishment is poorly known. However for most arable crops the optimum seedbed is composed of aggregates between about 1 and 10mm in diameter. As discussed above, aggregates <0.85mm in diameter are highly erodible and increase the likelihood of surface capping. In contrast, large dense aggregates (i.e. >10mm in diameter) are often impenetrable by roots, and can therefore restrict the soil volume from which roots can extract water and nutrients. Although poorly established, our best estimates suggest that the optimum seedbed for most arable crops is composed of at least 70% of its aggregates (by weight) in range of 1-10mm in diameter.
As discussed in later sections, peas are sensitive to compaction, both at the time of emergence and during crop development. Excessive wheel trafficking under wet conditions prior to sowing can result in topsoil compaction which in turn results in poor crop establishment. This is a particular problem with early spring sown peas and those crops sown on heavier soils where conditions tend to be wetter. Given the high incidence of soil compaction recorded in the pea crop monitoring project, we suspect that soil compaction is an important factor limiting pea crop performance in many soils. Further research is needed to define the critical soil conditions under which compaction restricts pea crop performance.

Compaction can also result from uncontrolled trafficking during the harvesting of peas. This is a particular problem where peas are contracted for harvest on a specific date or at specific stage of development. The resulting compaction often occurs deep in the soil profile and can be costly to reverse with cultivators, subsoilers or rippers. Where the compaction is not successfully reversed, areas of the paddock may suffer from poor drainage, increasing the risk that these areas will be exposed to further compaction. Compaction can affect crop production in several ways. Compacted layers can physically impede the downward penetration of roots, limiting their ability to extract water and nutrients from deeper in the soil profile. Where compaction is severe and wide-spread, it can also slow the drainage of water, creating anoxic (low oxygen) conditions that directly affect crop production by restricting root development and indirectly affect crop production by reducing the mineralisation (release) of plant available nutrients, including nitrogen. While these effects of pea crop harvesting may not have an immediate adverse affect on pea crop performance, they can markedly reduce the performance of other arable crops in the rotation. Care should be taken to avoid harvesting peas under wet conditions wherever possible and employing controlled trafficking practices will help to minimise the risk of compaction when conditions are wet at harvesting.

Table 3. A summary of results and optimum ranges for soil chemical and physical indicators.

Soil Indicators	Units	Optimum Range	Results of PIDG Study			
			Mean	Min	Max	Paddocks in Optimum Range (%)
Bulk density (0-15cm)	g/cm^3	< 1.25[3]	1.2	1.1	1.4	70
Bulk density (15-30cm)	g/cm^3	< 1.40[4]	1.4	1.2	1.8	48
Total C (0-15cm)	%	> 2.5[4]	2.6	2.1	3.8	45
Total N (0-15cm)	%	> 0.22[4]	0.23	0.17	0.31	45
pH	QT (2)	5.8-6.5[3]	5.8	5.4	6.3	59
Olsen P	QT	> 10[4]	18	6	50	62
Ca	QT	5-10[4]	10	7	16	62
Mg	QT	8-10[3]	20	7	51	7
Na	QT	5-20[4]	8	3	18	97
K	QT	3-8[3]	9	3	28	52
Cation exchange capacity	Me/100g	12-25[4]	16	12	22	100
Soil structural condition score	Score	5-10[3]	4.1	2.7	6.0	17
Penetration resistance (0-15cm)(1)	MPa	< 2.5[3]	2.5	1.1	4.2	48
Penetration resistance (15-25cm)(1)	MPa	unknown	4.2	2.7	7.0	
Aggregates <0.85mm	%	< 15[3]	19.3	3.6	30.8	24
Aggregate stability	MWD	> 1.5[3]	1.8	1.0	2.6	79

(1) All values normalised to 30% v/v soil moisture.
(2) QT = MAF Quick test units; MWD = mean weight diameter (excludes aggregates > 19mm diam.); NA = not available.
(3) Based on SQMS (see Soil Quality Management System User Manual for Canterbury Arable and Mixed Cropping Farms).
(4) Based on expert opinion.

NOTES

SOIL PREPARATION, SOWING METHOD AND SEEDING RATE

The best process pea crops achieve even emergence and target population, maintain crop health, don't produce excessive vine, have a compact flowering period and exhibit uniform maturity at harvest. Achieving these targets requires good practices at key stages:

- good uniform well-textured seed-bed, with available moisture, and sufficient nutrients;
- high quality uniform seed (processor responsibility);
- careful drilling to place undamaged seeds at correct spacing and uniform depth
- strategic pre- and post-emergence weed control and
- strategic irrigation when required - processor can advise optimum timings for cultivar and situation.

FAR, with help from the MAF Sustainable Farming Fund, has been working on crop establishment for four seasons in a project entitled Non-Inversion Agronomy. In three seasons (2004, 2006 & 2007) work carried out encompassed trials examining establishment options for combinable peas in the arable rotation. The following section has been compiled taking into account observations and research findings from this work.

KEY POINTS:

- Plant populations of 80-100 plants per m^2 are optimal for field peas, the target may be higher for vining peas.
- When working out target populations, take account of seedbed conditions as well as pea type; earlier spring sowings in colder and wetter seedbeds will increase field losses (seeds that don't germinate). These losses can be up to 20%.
- Sowing too fast can also cause reduced target plant populations. Target speeds of 5-10 kph are optimal. Using talcum powder to help increase the flow of seed through the drill may be beneficial, especially for large seeded cultivars.
- Avoid excessive cultivation wheeling since peas are sensitive to compaction, particularly on heavier soils or where earlier spring sowing is being attempted.
- Establishment technique can have a large influence on the need for subsequent herbicide inputs. As a general rule of thumb deeper cultivation and ploughing result in greater issues with broad leaf weeds, whilst direct sowing and minimal tillage create more issues with grass weeds. In general in spring sown peas, grass weeds are easier to control than broad leaf weeds, particularly under irrigation or in a wet season.
- Initial results indicate that grass forms a good entry for peas and also allows cultivation costs to be reduced. This is due to the fibrous nature of the top soil lending itself to less chance for soil compaction.
- Increased cultivation passes did not relate to increased yield in the PIDG bench-marking study carried out in 2006 & 2007. The mean cost of establishment based on 57 different pea crops was $220 – $250/ha depending on season and dry land versus irrigated.
- The optimum sowing period is late September to early October, although sowing of vining pea crops have to be staggered to provide continuity of supply to the processing facility during harvest.

THINGS TO CONSIDER WHEN ESTABLISHING PEAS

1. Target plant population in relation to seed bed conditions

Target plant population should be set against the plant type of the pea variety (e.g. Marrowfats, small blue); however equally important is to consider the seedbed conditions since field losses (i.e. those seeds that do not germinate due to field conditions) are likely to be higher with earlier spring sowings in cold seedbeds as compared to later spring sowings when seedbeds have warmed up. These field losses are quoted as anything between 5% - 20% under field conditions (Table 4).

Table 4. Expected field losses when establishing peas at different spring sowing dates (adapted from NIAB data - UK)

Expected Field Losses	Marrowfats	Others
Very early spring (Cold & Wet)	Up to 15%	Up to 18%
Spring (September)	10%	13%
Spring (October)	5%	7%

Losses can be higher on heavier poorly drained soils particularly with early spring plantings.

In addition losses are usually greater with smaller peas than larger marrowfats. The equation below is for calculating combinable pea seed rates in the UK; field losses are considered as an additional factor on top of seed stock germination (source PGRO - UK).

$$\text{Seed rate kg/ha} = \frac{(\text{TSW}) \times \text{target plant population}}{\%\ \text{Germination seed stock}} \times \frac{100}{100 - \text{expected}\ \%\ \text{field loss}}$$

TSW = thousand seed weight

Target plant populations for combining pea crops in New Zealand have been proposed at approximately 80 - 100 plants/m² from benchmarking and plant population studies (Figure 3)

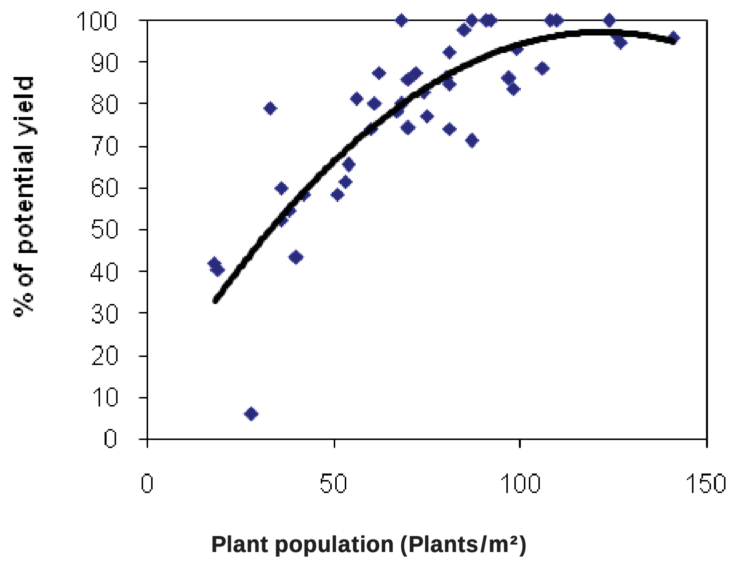


Figure 3. Relationship between established plant population and potential yield for data from four trials with a number of cultivars collected over three seasons (FAR Arable Update Pulses No. 7)

Where crops are not likely to reach their full potential, e.g. on shallow soils without irrigation, then target populations should be reduced to 70-80 plants/m². For vining peas which branch less, target plant populations should be around 100 plants/m²; however your contracts may stipulate other plant populations.

Trials have shown that at populations of:

- over 100 plants/m², the extra cost of seed reduces the crop profit;
- 75 plants/m², yields will be reduced by around 15% and
- 50 plants/m², yields will be reduced by around 30%.

2. Speed of sowing when establishing peas

Reduced establishment below target plant populations can frequently result from sowing peas too fast. At higher speeds, drill coulters, depending on drill design can bounce leaving peas at variable planting depth with some on the surface, particularly on stoney ground. Crop & Food Research carried out trials in 2006-07 which indicated that drilling slowly at 5-7kph allows for an even seed depth of 4-7cm and helps to avoid damaging large seeded cultivars such as the marrowfat varieties (Joint Industry Update No. 10).

3. Avoiding compaction

When considering cultivation strategies for peas it is important to recognise that they are sensitive to excessive cultivation wheeling and resultant compaction. This is particularly important where early spring sowing is being practiced, since as compared to the autumn, where the soil is moving from a dry phase to a wetter winter phase, spring sown crop establishment has to frequently wait until soils are dry enough for sowing.

Where minimal tillage or direct drilling is employed, as opposed to ploughing, there may be a greater need for patience before cultivation or sowing is attempted, as the seedbed will take longer to dry in the top surface, again particularly on heavier soils where soil aeration will also be a key factor. However Cambridge rolling pre-emergence, or as soon as the crop has emerged (for soils at risk of capping) will help reduce the amount of soil contamination at harvest, particularly for combining.

4. Influence of cultivation technique on resultant weed populations
Obviously there is a multitude of cultivation strategies that can be employed on farm, the majority of which are driven by the equipment available. In most cases many different establishment strategies can lead to the same yield output. However observations from the 2004 FAR Arable Site trial at Chertsey revealed that where there is a large weed bank of broad leaf weeds, establishment technique, whilst not influencing yield directly, can influence the resultant weed population (Figure 4).

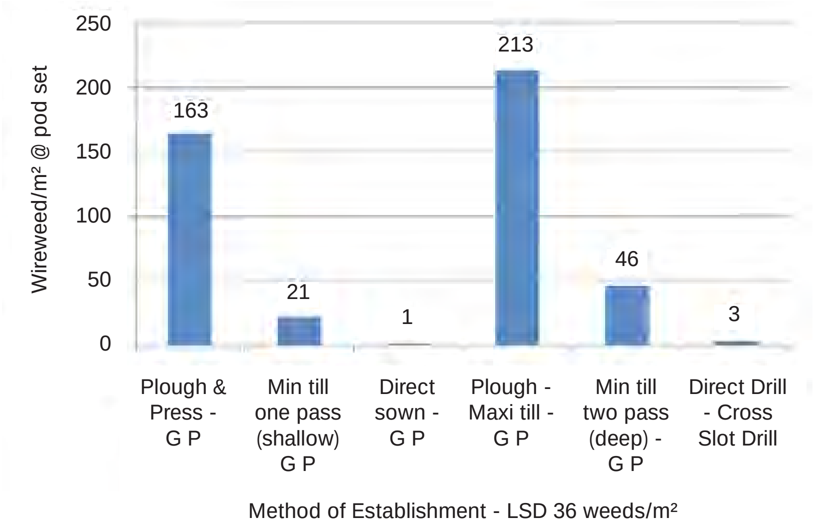


Figure 4. Influence of cultivation strategy on resultant broadleaf weed population in peas (assessed after herbicide application - FAR Arable Site 2004 cv Midlea)

GP = Great Plains or Triple Disc drill

Whilst all establishment blocks received the same pre emergence weed control, the very heavy broadleaf weed burden (wireweed) could not be controlled following ploughing. In contrast the minimal tillage and direct sown blocks, which received pre sowing glyphosate (see note Figure 5) and were subject to no soil inversion, were subject to far less weed pressure. At harvest this difference in weed pressure was very influential on yield; reducing yield in the plough blocks by nearly 1t/ha (Figure 5). Therefore where the broad leaf weed paddock history suggests a potential problem, remember that greater soil disturbance may result in much greater dependence on in-crop herbicides. Overall a general rule of thumb would suggest broad leaf weeds are more difficult to control in peas than grassweeds.

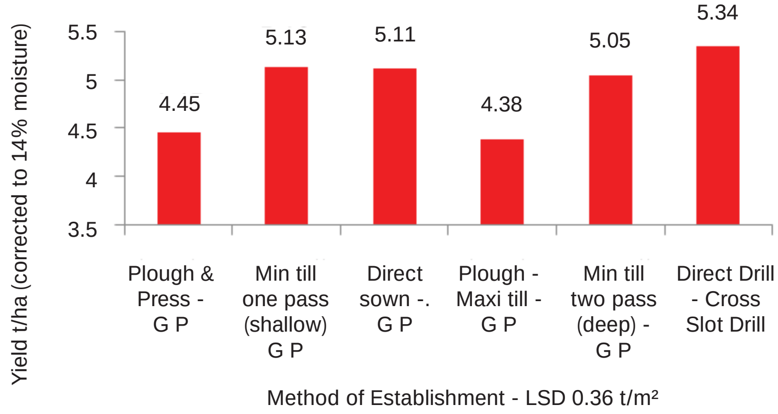


Figure 5. Influence of cultivation strategy on resultant pea yields following grazed greenfeed oats (FAR Arable Site 2004 cv Midlea)

**Note: Green feed oats after being grazed were destroyed with glyphosate prior to any cultivation (including the plough) for the pea crop.*

5. Establishment following grass
Being a spring sown crop peas are frequently sown following grass that has been kept down over winter for grazing purposes. In a recent MAF/FAR/CFR cropping survey it was apparent that the majority of growers establish crops after grass with the use of intensive cultivation (Figure 6). Whilst after long term pasture there may appear to be no other option than ploughing in order to avoid the dense mat of material in the base of the sward, there are many other situations following ryegrass seed crops where it may be possible to reduce the number of cultivation passes without impairing the yield output of the following peas. The fibrous nature of the top surface of the soil following grass lends itself to ideal conditions for reduced tillage, since it gives a less easily compacted seedbed from which to start.

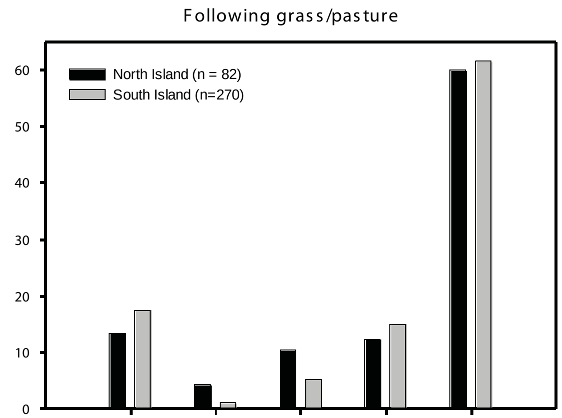


Figure 6. Primary form of tillage associated with arable crop establishment following grass/pasture (% of survey respondents – MAF/FAR/CFR 2006 Cropping Sequence Survey)

Working after 18 month ryegrass crops, initial results (Tables 5 & 6) have been promising, illustrating that minimal tillage and direct drilling can produce similar results to ploughing provided target plant populations are not greatly reduced by the chosen method of plant population (with small plant population reductions (2006) the crop will compensate but not with larger reductions).

Table 5. Influence of cultivation/establishment technique (number of passes) on establishment (plants/m²) and subsequent marrowfat pea yields (t/ha) following a ryegrass seed crop on a Wakanui Clay - sown 12 October 2006 cv Midichi - plant counts assessed 20 November 2006. (Trial run courtesy of Eric & Maxine Watson)

Trt No.	Primary Cultivation	Secondary Cultivation	Drill	No. of Passes	Plants/ m²	Yield t/ha
1	Plough followed by Press (4m)	Powerharrow (4m)	Simba Pronto Cultivation drill (4m)	4	52	4.88
2	He-Va Disc Roller with tyne sub-soiler (2 passes)	Powerharrow (4m)	Simba Pronto Cultivation drill (4m)	4	46	4.87
3	-		Direct sown - Cross Slot (3m)	1	42	4.75

Crop sown at 78 seeds/m²

Table 6. Influence of establishment technique (number of passes) on the yield (t/ha) of peas following ryegrass and the final plant numbers/m² - cv. Canty 778 sown 5 October 2007. (Trial run courtesy of Jim & Jenny Macartney)

Trt No.	Primary Cultivation	Secondary Cultivation	Drill	No. of Passes	Plants/ m²	Yield t/ha
1	Plough	Powerharrow (3m) f.b. roll Sunflower Cultivator	Duncan Hoe coulter drill (3m)	5	84	5.31
2	2 x Cultivation (Sunflower 6.7 m -tyne fitted)	Powerharrow (3m) f.b. roll Sunflower Cultivator	Duncan Hoe coulter drill (3m)	5	78	5.06
3	-		Direct sown - Cross Slot (3m)	1	75	4.71
LSD (5% significance)					15	0.52

COST OF ESTABLISHMENT - BENCHMARKING

As part of the PIDG project 57 different gross margins from 48 participants were compared over the 2005/06 and 2006/07 seasons. The following information relates to information gathered on the number of passes and costs of establishment and the relationship between the number of passes and resultant yield.

ESTABLISHMENT EXPENDITURE/HA

Note: Benchmarks are not presented for individual cost categories (Section 4.7 onwards, CropRight Benchmark Study), because uncertainty remains for each cost category's true influence on yield i.e. when graphed, less expenditure did not necessarily mean a reduced cost of production.

Table 7. Key statistics re establishment expenditure/ha

	Dryland		Irrigated	
	2005/06	2006/07	2005/06	2006/07
Min	$111	$108	$93	$116
Lower quartile	$166	$156	$197	$185
Mean	$217	$253	$222	$240
Upper quartile	$257	$321	$246	$273
Max	$343	$443	$378	$388

Establishment expenditure tended to be slightly higher in 2006/07 (Table 7) due to a greater number of secondary cultivations employed including rolling, maxi-tilling and power harrowing. The reasons why are not understood, but the data suggests growers spent more time and effort to create the pea seed bed that season.

ESTABLISHMENT PASSES ACROSS PADDOCK X YIELD RELATIONSHIP

Establishment passes include spraying off, cultivation, drilling & rolling passes, but not fertiliser spreading.

Increased establishment passes whether on dryland or irrigated crops did not increase yield (Figure 7). Furthermore when there were only two passes, there was no yield penalty. Hence growers should look to minimise establishment passes and hence establishment expenditure as much as possible.

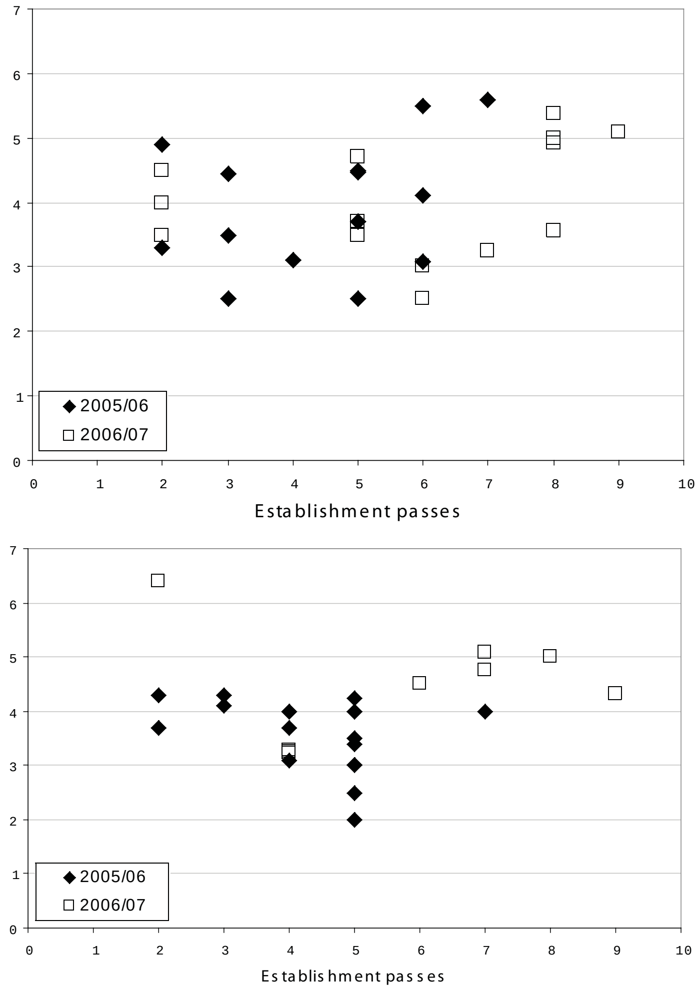


Figure 7. Establishment passes across paddock x yield relationship. Dryland & irrigated pea crops 2005/06 & 2006/07

SOWING DATE AND SOIL TEMPERATURE

Peas are sown from July to November, but optimum sowing dates for highest yields are usually late September and early October. However your seed or process company may have specific sowing date requirements. This is the case for process companies which need to stagger planting times and vining in response to the capacity of the processing factory. The sowing date will influence the choice of cultivar.

Peas will not normally germinate readily when 5cm soil temperatures are below 7°C for field peas and below 12°C for vining peas; so where appropriate sowings should be delayed until conditions are more favorable so that the crop can establish quickly.

SEED QUALITY

The seed lot should have a high germination (>90%), high purity and known thousand seed weight (TSW). This information can be obtained from the seed analysis certificate. Ideally the seed lot should be free of seed-borne pathogens. A pre-sowing health test will provide this information. Seed that has come from a Seed Certification Scheme or other in house certification scheme will help maintain the uniformity and integrity of the cultivars.

Seed that is treated with a fungicide will help control fungi present in the seed lot. Seed treatments can also protect young seedlings from soil borne pathogens that reduce establishment and from downy mildew at early stages of growth. Seed treatments for peas include Wakil, Apron® XL and Aliette Super. Use of seed treatments may be important early in the season; however research on pea establishment with and without fungicide seed treatment later in the season has shown no benefit. Seed lines with high seed borne disease loadings or sown into soils with high inoculum loads may still benefit from seed treatment.

ASSESSING ESTABLISHMENT, UNIFORMITY AND GROUND COVER

KEY POINTS

- Establishment is a good indicator of the yield potential of a crop.
- Plant counts can be used for establishment and uniformity estimates.
- % establishment =

$$\frac{\text{average number of plants established} * 100}{\text{number of seeds sown}}$$

- Established plants/m² (1 metre sample length) =

$$\frac{\text{average number of plants established/m row} * 100}{\text{drill width (cm)}}$$

- Uniformity can be important, especially in dry conditions.
- One measure of the uniformity of your crop =

$$\frac{\text{Average 5 lowest counts}}{\text{Average all counts}}$$

- Over 0.9 is uniform, under 0.7 is uneven.
- Ground cover is a measure of radiation interception.
- Ground cover can be assessed by the eye.

ESTABLISHMENT

The number of plants established is a good measure of the field preparation and sowing management, and gives an indication of the yield potential of the crop.

Take to the paddock a tape, a rod or a ruler 1m long. Pick out 20 spots at random in the paddock (ideally divide the paddock into two halves and take 10 readings at random from one end of half the paddock to the other and then return doing the same in the other half). At each spot, count all the plants in one 1m length of row. Calculate the average number of plants.

The % establishment $= \frac{\text{average number of plants established} * 100}{\text{number of seeds sown}}$

The established plant population in plants/m² (if your sample length is 1m)

$$= \frac{\text{average number of plants established} * 100}{\text{drill width (cm)}}$$

% establishment should be 90% under good conditions, and 75% under cold, wet conditions. Target plant populations are 80-100 plants/m² for field peas (70-80 on dryland shallow soils) and around 100 plants/m² for vining peas.

UNIFORMITY

A uniform crop will often yield higher than an uneven crop, especially in dryland conditions. Take the 20 establishment counts and rank them from highest to lowest. Take the average of all the counts, and of the five lowest counts. One measure of the uniformity of your crop $= \frac{\text{Average 5 lowest counts}}{\text{Average all counts}}$

A very uniform stand will have a value of over 0.9, whereas an uneven stand will have a value under 0.7.

GROUND COVER

Ground covered by your crop is a measure of how much radiation the crop is intercepting, a good indication of final seed yield. At the flat pod stage, pick out 20 spots at random in the paddock (as above). At each spot, look vertically downwards and assess how much ground and weeds you can see (in multiples of 10%) between the pea plants. If you estimate that 20% of what you see is ground and 10% is weeds, then the ground cover of the pea crop at that spot is 70%. Calculate the average ground cover. With good management and establishment, the ground cover should be 90%.

NOTES

RADIATION, TEMPERATURE AND TIME

KEY POINTS

- Growth and development of peas, and therefore potential yield, depend on solar radiation and temperature during the life of a crop.
- The relationships are simple and predictable and can be used to estimate potential growth and yield for any combination of cultivar, sowing date and climate.
- Growth is driven by the amount of radiation intercepted by a crop's leaf canopy:
  - The longer a crop grows, the more radiation it can intercept and the more it can produce - unless it is growing at a time of year when radiation is low.
  - Growth is often limited by inability to intercept radiation because of failure to produce and maintain a full leaf canopy - caused by agronomic factors such as water stress, low plant population, foliar diseases, etc.
- Development (rate of progress through the life cycle) is driven by temperature:
  - Growth duration is longer, therefore potential yield is higher in cooler conditions because the crop develops slower.
  - Most cultivars have a similar development response to temperature; a good indicator is the rate at which they produce nodes as stems elongate.
  - The main development difference between cultivars is in the number of nodes that they produce.
  - Development from sowing to flowering and maturity is quantified in thermal time (°C days, or heat units).
  - Agronomic factors have little influence on development.
- Economic yield depends on how much growth is allocated to seed:
  - The percentage is called the harvest index.
  - It differs among cultivars and is often reduced by agronomic factors, especially stresses during seed fill – water deficit, foliar diseases, etc.
- Sowing date strongly influences all these factors:
  - It determines the radiation and temperature experienced by a crop.
  - Crops sown earlier usually have higher yield potential because they experience cooler temperatures, so they develop slower, grow for longer and therefore intercept more radiation.
  - In contrast, crops sown later develop faster, grow for less time, intercept less radiation and, therefore, have lower yield potential.

GROWTH IS DRIVEN BY THE AMOUNT OF SOLAR RADIATION INTERCEPTED BY A CROP'S LEAF CANOPY

- There is a simple straight-line relationship between growth and intercepted radiation: about 0.9g of dry matter (DM) is produced for every MJ/m² of radiation (Figure 8).
- The daily DM growth rate of an unstressed crop with a full leaf canopy can be calculated from the solar radiation:
  - For example, on a clear mid-summer day with 25 MJ/m² of solar radiation the growth rate is about 0.9 x 25 = 22.5g/m² (or 225kg/ha).

- In contrast, the growth rate on a dull, cloudy day with 5 MJ/m² of solar radiation is only about 0.9 x 5 = 4.5g/m² (or 45kg/ha).

- Therefore, the longer a crop grows, the more radiation it can intercept and the more it can produce.
- Radiation interception, and therefore growth, is often reduced because of failure to produce and maintain a full leaf canopy:
  - This is commonly caused by agronomic factors such as water stress, low plant population, foliar diseases, etc.

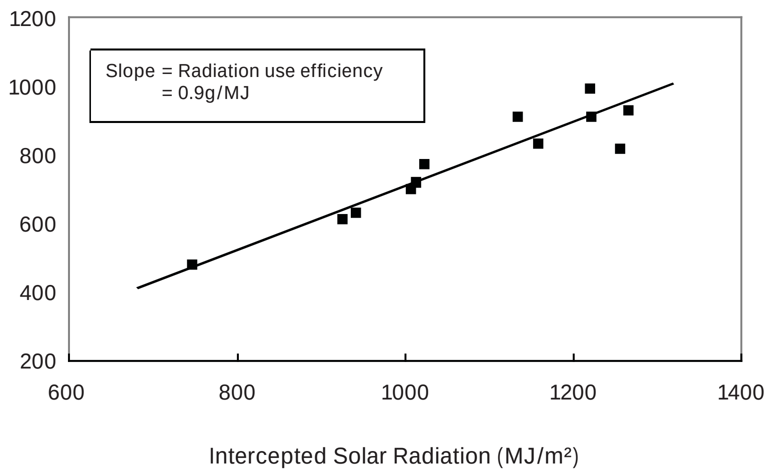


Figure 8. Relationship between total dry matter yield of field peas (cv. 'Rovar') and intercepted solar radiation in 12 irrigation treatments in an experiment in the rainshelter at Lincoln.

CROP DEVELOPMENT IS DRIVEN BY TEMPERATURE

- Growth duration depends on the thermal time (°C days or heat units) requirement from sowing to flowering and maturity.
- This requirement is stable for each cultivar but varies widely among pea cultivars:
  - Most cultivars have a similar development response to temperature.
  - A good indicator is the rate at which they produce nodes as stems elongate.
  - The main development difference between cultivars is the number of nodes that they produce.
- Duration is short in warm conditions and long when it is cooler.
  - For example, if the mean temperature is 16°C during the life of a cultivar with a thermal time requirement of 1200 °C days, it will take 1200/16 = 75 days from sowing to maturity.
  - In contrast, if the mean temperature is only 12°C, the same cultivar will take 1200/12 = 100 days from sowing to maturity.
- Therefore, potential yield is usually higher in cooler conditions because crops grow for longer.
- Agronomic factors have little influence on development.

TOTAL DRY MATTER YIELD CAN BE CALCULATED AS THE SUM OF DAILY GROWTH RATES DURING THE LIFE OF A CROP

- For example, if daily solar radiation averages 20 MJ/m² and the temperature averages 16°C, the potential total DM yield of the 1200 °C day cultivar is 0.9 x 20 x 75 = 1350 g/m² (or 13.50 t/ha).
- In contrast, if daily radiation averages only 15 MJ/ m², the potential total DM yield of the same cultivar is reduced to 0.9 x 15 x 75 = 1012 g/m² (or 10.12 t/ha).

SEED YIELD DEPENDS ON HOW MUCH OF THE TOTAL YIELD IS ALLOCATED TO SEED

- The percentage is called the harvest index.
- It differs among cultivars and usually ranges from about 45 to 55%.
- Assuming an average of 50%, the potential seed yields (DM) for the examples above are about 6.75 and 5.06 t/ha respectively (i.e. 50% of 13.50 and 10.12).
- Harvest index is often reduced by agronomic factors, especially stresses during seed fill such as water deficit or foliar diseases.

SOWING DATE STRONGLY INFLUENCES ALL THE YIELD-DETERMINING FACTORS

- Sowing date determines the radiation and temperature experienced by a crop.
- Crops sown earlier usually have higher yield potential because they experience cooler temperatures, so they develop slower, grow for longer and therefore intercept more radiation.
- In contrast, crops sown later develop faster, grow for less time, intercept less radiation and therefore have lower yield potential.

When considering vining peas, air temperature is the major factor determining how long a crop takes to reach maturity. Most processors use growing degree days (GDD) to determine the required sowing date to match a target harvest date. Different cultivars have different GDD requirements, and different geographical locations will influence the expected GDD a crop will experience.

Of course every season is different! Planting plans based on long term average temperatures can come unstuck when the climate turns warmer or cooler than is usual for the region. In Canterbury a few consecutive days of hot dry Nor'westers can bring too many crops onto maturity faster than the factory can process - some may have to be bypassed.

ASSESSING YIELD

KEY NOTES
- The potential yield of a crop can be calculated by multiplying the expected yield components.
  - Number of peas per m², which depends on plant population and the number of peas per plant.
  - Number of peas per plant depends on the number of pods and the number of peas per pod.
  - Mean pea weight.
- For example, calculate the yield as:
  Yield = 80 (plants/m²) x 5 (pods/plant) x 5 (peas/pod) x 0.25 (g/seed) = 500g/m² or 5 t/ha.
- Yield stability is often maintained by a lot of compensation among the yield components. For example, peas per plant can increase substantially if plant population is low.

The number of pods formed per m² is highly influenced by management factors, such as plant populations and soil moisture. Other yield components are influenced more by the type of pea than by management factors, such as pea size and number of peas per pod.

Table 8 shows how target pod numbers to achieve either a 5 or 8 t/ha seed pea crop change as expected seed weight and likely pea numbers per pod change. This type of information can give an indication of what the final weed yield will be under good management. As pea plants have a high ability to compensate for deficiencies in the various components of yield, the targets are a guide only.

Table 8. Target yield components for a 5 and 8 t/ha pea crop

	5 t/ha crop			8 t/ha crop		
TSW (g)	Required no. of peas/m²	Approx. no. of peas/pod	Required no. of pods/m²	Required no. of peas/m²	Approx. no. of peas/pod	Required no. of pods/m²
200	2500	5	500	4000	5	800
200	2500	8	313	4000	8	500
300	1670	5	334	2667	5	533
300	1670	7	239	2667	7	381
400	1250	4	313	2000	4	500
400	1250	6	208	2000	6	333

WATER MANAGEMENT

Pea yields depend strongly on water supply, and crops are sensitive to either water deficit or surplus. The economics of irrigating can be marginal so it is important to assess the cost:benefit and give priority to crops with higher yield potential. Dryland crops should be managed using strategies to maximise their use of limited available water and in-season rainfall.

IRRIGATED CROPS

KEYPOINTS
- Yield responses to irrigation are variable ranging from reductions in wet seasons or locations to large increases in dry conditions.
- It is important to analyse the cost benefit to avoid uneconomic irrigations.
- Water deficit should be monitored and crops irrigated when water is needed (before the critical soil moisture deficit is exceeded) regardless of growth stage.
- Frequent, small irrigations are more beneficial than infrequent large ones.

To maximise yield and get the best return from each mm of water, pea crops should be irrigated when they need water, regardless of growth stage. There is no evidence that peas are more sensitive to water deficit at any particular growth stages such as during flowering or seed growth. The water deficit should be monitored to ensure that the critical PSMD (potential soil moisture deficit) is not exceeded. This can be done either by using a soil water monitoring service, which regularly measures soil moisture content, calculates the water deficit and reports on the irrigation requirement, or by doing a water budget, estimating the soil water deficit and making the irrigation scheduling decisions yourself.

WATER BUDGETS

Water budgets can be done either by a scheduling service or by keeping rainfall records and using potential evapotranspiration (PET) figures which are published in newspaper weather reports. To plan ahead, average PET figures can be used for the coming days (Table 9).

Table 9. Average daily PET for each month in Canterbury

August	1.6mm/day
September	2.3mm/day
October	3.4mm/day
November	4.1mm/day
December	4.6mm/day
January	4.9mm/day
February	4.2mm/day
March	3.1mm/day
April	2.1mm/day

The following information is required, all in mm of water:

- The PSMD at the start of the season. It is usually zero but may be large after a very dry winter. In this case, start irrigating early as soil that is dry at depth behaves as a shallow soil. Although you can set PSMD to zero for the calculations - remember that you started with dry soil.
- PET.
- Rainfall, ideally measured on your own farm.
- Irrigation applied.

Calculate the PSMD each day or week as follows:
PSMD (today) = PSMD (last time) - PET + Rainfall + Irrigation

See Table 10 for an example of a typical seasonal water budget, with PSMD calculated each week.

Table 10. Example water budget. Weekly water budget for the 2007-08 season. All figures are in mm. Rainfall data is from Chertsey and PET values are the average figures from Table 9. Based on a soil depth of 1m the critical PSMD is 65mm. Highlighted PSMD figures indicate the need to irrigate

Date	Rain	PET	Irrigation	PSMD
3 - 9 Sept	4	16.1		-12.1
10 - 16 Sept	0	16.1		-28.2
17 - 23 Sept	11	16.1		-33.3
24-30 Sept	6	16.1		-43.4
1-7 Oct	10	23.8		-57.2
8-14 Oct	31	23.8		-50
15-21 Oct	8	23.8		-65.8
22-28 Oct	2	23.8		-87.6
29 Oct-4 Nov	0	26.6	50	-64.2
5-11 Nov	2	28.7		-90.9
12-18 Nov	28	28.7	50	-41.6
19-25 Nov	0	28.7		-70.3
26 Nov-2 Dec	7	29.7	50	-43
2-9 Dec	0	32.2	50	-25.2
10-16 Dec	12	32.2		-45.4
17-23 Dec	21	32.2		-56.6
24-30 Dec	8	32.2	50	-30.8
31 Dec-6 Jan	0	34		-64.8
7-13 Jan	0	34.3	50	-49.1
14-20 Jan	0	34.3		-83.4
21-27 Jan	16	34.3		-101.7

INTERVAL BETWEEN IRRIGATIONS

To achieve its potential yield, a crop should be irrigated so that the PSMD never falls below the critical value (CV). The CV can be determined as follows:

- It is half the available water holding capacity (AWC) in the root zone.
- The AWC depends on rooting depth and how much of the rooting depth is in soil and how much is in gravel.
- Typical AWC and CV values are in Table 11, based on a rooting depth of 0.8 m, which is typical for peas if there is no restriction caused by compacted soil layers.
- As a general rule the AWC is 165mm per metre of soil depth and 55mm per metre of gravel depth: AWC = (Soil depth(m) x 165) + [(Root depth – soil depth) x 55]. Thus, the interval between irrigations depends on rooting depth and soil depth.

Table 11. Typical values for available water holding capacity (AWC) and critical PSMD

Soil Depth to Gravel (m)	AWC (mm)	Critical PSMD (mm)
0.20	66	33
0.40	88	44
0.60	110	55
0.80	132	66
1.00	132	66

TIMING OF IRRIGATION

Water deficit should be monitored and crops irrigated whenever they need water (i.e. whenever PSMD approaches the critical value). Frequency and volume of water applied is more important than timing for yield responses and economic margins as the results in Table 12 demonstrate.

Table 12. Influence of irrigation treatments on yield in a marrowfat pea trial (f = weeks of full irrigation, n = weeks of no irrigation) and the resulting return per ha assuming two costs per mm of water applied (Value of seed $1000/t)

Trt	Increased yield over nil irrigation (t/ha)	Extra value of seed ($/ha)	Water applied mm	Return over cost of water applied ($/ha)		Kg/seed per mm water applied
				$1.50/mm	$2.00/mm	
3f+9n	0.58	580	108	418	364	5.4
9f+3n	0.94	940	248	568	444	3.8
3n+9f	0.93	930	216	606	488	4.3
9n+3f	0.51	510	84	384	342	6.1
Full	1.18	1180	379	611	422	3.1

COST:BENEFIT

Assess the cost:benefit by estimating (a) the cost per mm of irrigation (including infrastructure and operating costs) and (b) the value per kg of extra yield, then (c) look up the economic return value in Table 13. The values in the table were calculated assuming a 50mm application per irrigation. The economic return is more likely to be positive when the cost of irrigation is lower, for a crop with higher yield potential and / or higher seed value. Therefore priority should be given to crops with high seed yield and / or value as economic returns from irrigating are higher.

Table 13. Economic return ($ / ha) from a 50mm irrigation

Potential Yield (t/ha)	Irrigation Cost ($/mm)	Seed value ($/t)			
		400	600	800	1000
3.0	1.50	57	123	189	255
	2.00	32	98	164	230
	3.00	-18	48	114	180
	4.00	-68	-2	64	130
4.0	1.50	101	189	277	321
	2.00	76	164	252	340
	3.00	26	114	202	290
	4.00	-24	64	152	240
5.0	1.50	145	255	365	475
	2.00	120	230	340	450
	3.00	70	180	290	400
	4.00	20	130	240	350

PRACTICAL CONSIDERATIONS

- Small frequent irrigations are better than large infrequent ones as:
  - water is likely to be used more efficiently as availability and crop demand are better balanced;
  - with small irrigations waterlogging and associated leaching of nutrients are less likely to occur;
  - rainfall is utilised better when it occurs, keeping the irrigation costs down;
  - peas are sensitive to over-watering, with too much water resulting in reduced yields and
  - any excess irrigation over the refill point is wasting water and money and could reduce yield.
- Irrigate before the critical deficit is exceeded, regardless of growth stage:
  - Start too late and there is no way to recover the lost potential yield.
  - Stop too early and water deficits develop quickly as losses through ET are higher.
  - Adequate water throughout seed growth is essential - in high potential crops, seed yield accumulates at about 150 kg/ha/day.
  - Yield can be reduced by approximately 1 t/ha for every seven days that seed growth is shortened by water deficit.
  - Bear in mind the length of pod fill averages 40 days - at an average ET of 5mm/day, crops need about 200mm of water during this period.

- Provide an optimum rooting environment for crops to maximise the volume of soil water they can access. Refer to sections on soil quality and soil preparation.
- Irrigation alone will not produce a high yield - good irrigation management needs to be backed up with good crop husbandry.

DRYLAND CROPS

KEY POINTS

- Yield is limited by the amount of water available from stored soil water and in-season rainfall.
- Avoid light soils with low water holding capacity.
- Sow early to avoid mid and late season drought.
- Choose early maturing, semi-leafless cultivars.
- Manage crops to maximise water use efficiency eg. minimum cultivation can provide an extra 40mm of water.

Water availability is a major cause of yield variability in dryland crops. They need to be managed to minimise the risk of low yield by making the best of the limited stored soil water and in-season rainfall.

Soil water content is known at the start of the season. At field capacity, water available in the 0.8m root zone ranges from about 70mm in light, shallow soils to 140mm in heavier, deeper soils (see Table 11 for typical available water holding capacity values). Without in-season rainfall this is enough water to produce yields of 0.7–1.3 t/ha. Most crops produce more than this as stressed plants use water very efficiently and probably extract water from greater soil depth than unstressed plants. Additional yield depends on the amount of in-season rainfall which varies from year-to-year.

PRACTICAL CONSIDERATIONS

- Avoid growing dryland pea crops in light soils with low water holding capacity. The critical PSMD is small and the risk of low yield is high in seasons with low rainfall. Heavier soils have more water available at the start of the season and can retain more water from rainfall events during the season.
- Sow early to avoid mid and late season drought. Damaging water deficit is likely later in the season so the risk of deficit before maturity is reduced by sowing early.
- In east coast regions of New Zealand where peas are most commonly grown, the long-term average rainfall is about the same every month of the year (at Lincoln the average is about 55mm/month). However rainfall per month is very variable among years, so yield variability from year-to-year depends mainly on rainfall.
- PET is highest in summer months but is more consistent than rainfall from year-to year. At Lincoln, ET ranges from 30mm/month in June to 70mm in September and 150mm in January (see Table 9).
- Therefore the gap between rainfall and ET, which creates water deficit, is greatest during summer months.
- Choose early-maturing, semi-leafless cultivars:
  - Combined with early sowing, cultivars with a low thermal time requirement reach harvest maturity earlier so are more likely to avoid exposure to mid and late season drought.
  - Water is conserved early in the season by semi-leafless cultivars with slower leaf canopy development and therefore capacity to intercept solar radiation is greater.

- Leaf area of semi-leafless cultivars is less sensitive to water deficit.
- Potential yield is less when a wet season occurs but the risk is reduced in dry seasons.

- Good weed control is important to reduce competition for available water and the non-productive use of water through transpiration by weeds.
- Once a leaf canopy is established, it should be maintained to reduce water loss by evaporation from soil after rainfall events. This ensures water loss is mainly through transpiration of pea plants.

SOIL FERTILITY AND FERTILISER

KEY POINTS

- Obtain a soil test.
- Under optimum fertility, fertiliser application is not necessary.
- Where soil fertility has been depleted, fertiliser application may be warranted.
- Use of fertiliser as insurance should be kept to a minimum.

Research throughout New Zealand (FAR Arable Update Pulses No. 6) has confirmed that peas do not respond to the application of nitrogen (N), phosphorus (P) or potassium (K) fertilisers, so that the practice of applying fertiliser to both process and field pea crops is likely to be unnecessary and unprofitable. This is the result of over 25 replicated trials, followed by four years of on farm research. Applying fertiliser to peas consistently (though not significantly) reduced yield by an average of 6% and consistently reduced emergence by approximately 11%. There is a loss to the farmer from fertiliser that was wasted, seed that did not emerge and the overall yeild loss. Using 2008 prices these equate to a loss of income of between $365 and $570/ha.

However, if Olsen P is <10-15µg/g or K is <3µg/g (i.e. severely depleted), then an economic yield response to the application of P and K may occur, especially in crops with high yield potential. In such cases apply potassic super. Applying N will not increase pea yields, and may depress biological N fixation by inhibiting nodule formation and functioning. Requirements for trace elements are poorly understood; it may be beneficial to correct any severe deficiencies at sowing. Soil pH at sowing should be 6.0 to 6.5, correct a low pH by applying lime.

The CropRight benchmarking study on 33 marrowfat crops grown over the 2005/06 and 2006/07 seasons, indicated that crops that had fertiliser applied showed no increase in yield compared to the crops where there was no fertiliser applied.

WEED CONTROL

KEY POINTS

- Peas are badly affected by competition from weeds.
- There are pre-emergence and post-emergence herbicide options for weed control in peas.
- Targeting weeds at early weed growth stages will result in optimal control.
- Obtain the best advice from industry representatives on the selection and rate of herbicides to target the weeds present in a crop.

Peas are very susceptible to competition from weeds, particularly in the early stage of crop development. Whilst weed competition can have a big impact on yield, pea plants that are weak are also more susceptible to pests and diseases.

There are two methods of weed control available; pre-emergence and post-emergence. Trifluralin is commonly used as a pre-emergence weed control in peas. To achieve the best results from Trifluralin it is best applied to a well worked flat seed bed, free of rubbish or large clods and incorporated immediately after application. Working in two different directions is required for thorough incorporation. For best results use heavy spike or diamond harrows or dutch harrows.

Trifluralin controls susceptible weed species by killing seedlings as they germinate so it is important to have the Trifluralin incorporated in the top 5cm of the soil. Trifluralin controls a wide range of weeds but is very good for the control of wireweed, spurrey, chickweed, fathen and annual poa. Incorporation and the correct application rate is vital for the success of trifluralin.

Another means of controlling weeds in your pea crop is by applying Terbuthylazine (trade names Gardoprim and Terb500) pre-emergence. It must be applied after drilling but before crop emergence. Terbuthylazine controls a range of weeds including black nightshade, fathen, fumitory and others but you need a firm fine moist seed bed for it to work.

There are several chemicals available for the control of weeds in peas post-emergence. The choice of the correct chemical or mixture of chemicals is obviously dependent on the range of weeds present. When applying a post-emergence herbicide it is very important to wait until pea plants have a complete wax cover to avoid injuring the crop, particularly after rainfall and/or rolling of the peas.

Some of the common post-emergence chemicals are: metribuzin - trade names Sencor, Lexone and Jazz are very good for the control of wireweed, fumitory, speedwell, fathen, willow weed and several others. Cyanazine - trade names Bladex and Bruno are very good for the control of black nightshade, calandrinia, cornbind and several others.

There are some other herbicides used on peas post-emergence and these include Pulsar (bentazone & MCPB) which has a broad spectrum of weeds including cleavers, field madder, stinking mayweed and a lot more.

Tropotox Plus, Select and Thistrol Plus are all a combination of MCPB and MCPA and are mainly used for fathen and thistle control.

There are various mixtures that can be used but this is very dependent on the weed species present; however one common mixture is Metribuzin and Cyanazine combined. Californian Thistles are a major problem in a paddock of peas and the only effective control is to avoid all paddocks with Californian Thistles in them.

Controlling of grass weeds in peas is just as important as the control of your broadleaf weeds. Grass weeds can be very competitive and need to be removed from the crop. In an intensive arable situation a pea crop is one of the few opportunities that you have to clean up your grass weeds, particularly the brome species. There are several registered chemicals that can be used on peas and these include Gallant NF, Ignite, Centurion Plus, Fusilade Forte and Leopard. All of these products do a very good job at controlling grass weeds.

As with all weed spraying the earlier you can remove the competition the better. When you are using a selective grass killer please read the label first and contact your local adviser or company representative to make sure you are using the right rate for what you want to do.

With more semi leafless varieties being grown the weed control is more important. As with all weed spraying the earlier you can get it done the better, you remove the competition and you are giving the pea crop the best chance of success.

It is very important that you read the label and ask your adviser or company representative for the right product for you.

The New Zealand Novachem Agrichemical Manual is also available online at www.spraybible.com for further information on registered agrichemicals in New Zealand.

Another aspect of weed control is the transfer of diseases to peas from other plants, especially legumes. This is particularly important with virus diseases that are transmitted by aphids. Ensure that clover or lucerne weeds growing near pea crops are kept under control to prevent the transmission of diseases like alfalfa mosaic virus, top yellows, pea mosaic virus (=bean yellow mosaic virus) and pea seedborne mosaic virus.

PESTS AND DISEASES

KEY POINTS

Insects, Virus and Control

- Aphids are considered the major insect pest in peas; however slugs and leaf minors can be found in crops.
- Virus such as PSbMV and the other mosaic viruses are spread by aphids. Aphid numbers tend to build up in October, so early monitoring and action may be necessary to control populations.
- Apply a systemic insecticide early and again later if aphid numbers reach 2-3/plant.
- Continue to monitor crops throughout the season and take control measures if necessary.

Diseases and Control

- Problem diseases can include Aphanomyces root rot, Ascochyta blight, Downy and Powdery mildews, Bacterial blight and Pea Seed-borne Mosaic Virus (PSbMV).
- Monitor the crop every week to check for the presence of disease; be pro-active and spray to prevent disease build-up from as early as the 6th-7th node stage. Sowing disease free seed is the most effective way to control Bacterial blight.
- Crop rotation is important when considering disease control in peas. A minimum of four to five years between crops will help to ensure soil borne diseases such as the root rots (which can not be controlled by fungicide) are less of a problem.
- Hygiene is also an issue when controlling diseases, especially Bacterial blight. Keep dogs out of crops and disinfect footwear between crops - blight is readily transferred by such methods.

INSECT PESTS

Insect pests are not considered a problem in pea crops, with the exception of aphids. Virus diseases are transmitted by aphids. Aphid numbers build up in October, so early action to minimise spread is required; apply a systemic insecticide. Monitor the crop and neighbouring crops and spray again if aphid numbers exceed 2-3/plant. (Source: FAR Arable Update Pulses No. 8, Best management guide for pea crops, Nov 2002)

SLUGS

When conditions are favourable, slugs can cause significant damage to emerging pea crops by either feeding on the seeds or emerging plants. At sowing it is important to ensure good soil/seed contact to minimise slug feeding on the seeds. It is also important to monitor slug numbers near the time of sowing to help determine need for applying slug controls.

Slugs are highly dependent on moisture for feeding, survival and reproduction and are at their most damaging in wet weather. High levels of surface trash provides an ideal habitat for slugs and they can cause severe damage when crops are drilled during a period of wet weather or when soil moisture is generally high.

There are four pest species of slugs found in Canterbury, with the grey field slug being the most important pest. This species is very responsive to changes in moisture and will become active extremely quickly when conditions become favourable. It is important to become familiar with the slug species present as not all slugs cause severe damage (refer to Arable Extra No. 46 for slug identification).

Monitoring of individual pea crops needs to continue until they are well established, as slug numbers can increase to problem levels over very short periods. If monitoring indicates that a baiting is required then beneficial predators that can also contribute to slug control should be considered. There are a number of carabid beetle species that feed on slugs at various stages of the slug lifecycle, however these beetles will also be killed by methiocarb-based slug baits as well as organophosphate and synthetic pyrethroid insecticides. EDTA or metaldehyde slug baits are more pest specific and will have little effect on these beneficial beetles. (Source: FAR Arable Extra No. 66, Slug management using IPM, May 2007)

Figure 9. Grey field slug (Derocerus reticulatum).

FUNGAL DISEASES

SEED AND SEEDLING DISEASES

Various species of *Pythium* and *Fusarium*, and *Rhizoctonia solani* have been associated with seed decay and seedling blights in peas. These pathogens can rot seeds before they germinate. Seedlings may rot at the soil surface, known as 'damping off', especially after extended periods of wet soil conditions.

Symptoms: Patchy crop establishment, low seed germination, rotting of seed, weak growth, 'damping off' of seedlings.

Control: Use certified, high germination seed and well-prepared, well drained seedbeds with adequate moisture. Use of fungicide seed treatment is recommended.

ASCOCHYTA BLIGHT

Ascochyta blight is a major disease of pea crops in New Zealand. It is caused by a complex of three closely related pathogenic fungi. These are:

- *Mycosphaerella pinodes* (sexual stage of *Ascochyta pinodes*) causes Ascochyta blight;
- *Phoma medicaginis* var. *pinodella* (also known as *Ascochyta pinodella*) causes Ascochyta foot rot
- *Ascochyta pisi* causes leaf and pod spot.

Symptoms: The main fungus causing Ascochyta blight in New Zealand is *M. pinodes*. This pathogen causes dark irregular spots on leaves and stems. The spots may grow together to form larger lesions. In severe infections the leaves may dry up but remain attached to the affected plants. Most lesions are found on the lower leaves and stems which are closer to the stubble-borne inoculum on the soil surface. Stem lesions are usually first found at the points of leaf attachment and are brown to purple. In severe cases whole stems may be covered with lesions. The lesions may also occur on flower stalks before flowering ceases, causing blossom drop. Lesions form on pods and the fungus can also infect the seeds. Seeds in older pods are more susceptible to damage. Infected seed may appear normal, or may be shrunken and discoloured.

Lesions caused by Ascochyta foot rot are commonly more concentrated at the bases of affected stems and near the point where the cotyledons are attached. Blackening of the taproots and stem bases of plants may also occur. Early season infection leads to collapse of plants as the first pods fill, resulting in premature lodging and reductions in yield and quality.

Primary infection and disease cycle: The pathogens causing Ascochyta blight have four main sources of primary inoculum: seed, plant debris, soil and volunteers. The importance of these different sources varies depending on cultivar species, cropping practices and climatic factors. As well as seed, infected plant debris is the major source of infection of *M. pinodes* in established pea-growing areas. *Phoma medicaginis* var. *pinodella* also persists in fields by producing spores that can survive in the soil for 10 years or more. *Ascochyta pisi* is a weak saprophyte and over-wintering in the field is not important, but seed-borne carry-over is extremely important. Internal seed infection for this pathogen is rare and most inoculum is carried externally in dust or small straw particles. The disease cycle of *M. pinodes* starts with the release of ascospores. Pseudothecia, which are formed on senescent tissue, start releasing ascospores after rain, which are dispersed over long distances by wind. Under favourable conditions, infection occurs and lesions appear on the leaves and stems. Pycnidia (pin head size black dots) develop on the infected tissue and produce spores (conidia) that can be rain spread to give secondary infection. After colonisation of plant tissue, the fungus survives on straw fragments and in the soil. Temperature and moisture are the two key factors influencing the progress of the disease.

Cultural control: Long rotations are required as *M. pinodes* survives for long periods on crop residue in the soil. Eliminate residues by deep-ploughing or burning.

Chemical control: Treat seed with approved fungicide to prevent seed transmission. For foliar fungicide applications, the research funded by the PIDG and MAF Sustainable Farming Fund has identified the importance of disease identification and monitoring of crops in order to apply fungicides at the early stages of Ascochyta blight development. Significant yield increases were observed when fungicides were applied soon after the first signs of the disease appeared on the lower leaves of the plant. Amistar (*azoxystrobin*), Comet (*pyracostrobin*), Proline (*prothioconazole*) and Protek (*carbendazim*) (not all are registered for use on peas) were all, either alone or in combination, effective in controlling Ascochyta blight and significantly increasing yield. The results suggested that an early fungicide application prior to 5% disease incidence combined with a fungicide application later before canopy closure was critical for controlling Ascochyta blight.

Disease forecasting: Few forecasting models for Ascochyta blight prediction on peas have been published. A French research team predicted impact of Ascochyta blight on pea yield components by studying both disease progression in the canopy (number of nodes affected) and the structure of the canopy (leaf area index profile; Le May et al. 2005).

An Australian research team from the Department of Agriculture and Food Western Australia (DAFWA) created a model using historical weather data to forecast disease development under different weather scenarios (Salam et al 2006). They found that summer and autumn weather conditions at ascospore release were critical in determining sowing dates, in order to avoid spore deposition on the newly establishing crop. This model has been incorporated into "Blackspot Manager" (http://www.agric.wa.gov.au/cropdiseases under 'Crop disease forecast 2008' 'South Australia'), which identifies whether the delay in sowing is necessary or if it is safe for peas to be sown during the autumn. For south Australia, early sowing is possible when "Blackspot Manager" indicates that the risk of airborne spores is low. Low rainfall areas benefit from early sowing but areas of high rainfall may not benefit as higher rainfall increases the risk of secondary infection within the crop. In addition to timing of sowing, it is also important to avoid planting peas adjacent to pea stubbles, this is to avoid water logging and to have a minimum of three year rotations, but preferably five year rotations between pea crops.

A Canadian decision support system to evaluate the risk of Ascochyta development in pea crops has been developed at Agriculture and Agri-Food Canada, Saskatoon Research Centre. The system is based on a set of guidelines for identifying situations where foliar fungicide application is most cost effective. It identifies risk factors that best describe:

- plant stand (from thin to dense);
- number of days with rain in the last 14 days (from 0 to 7 days or more);
- five-day weather forecast (rainfall) and
- amount of disease (from 0 to 50% leaf area infected).

The relative risks associated with each factor that control disease development are calculated to get a risk value. A fungicide application is recommended when a threshold risk value is exceeded. If the risk value is not exceeded, a fungicide application is not recommended, but a new assessment is recommended every three to five days until the crop is no longer flowering. The pea blight forecaster prototype developed as part of the PIDG research programme uses the Canadian risk value system, but is modified to the local conditions based on data collected from several field trials during the growing seasons from 2004 to 2008. The prototype disease forecaster will be tested on a limited scale from the 2008-09 growing season.

Figure 10.
Lesions caused by Mycosphaerella pinodes

Figure 11.
Pea pods with light to severe Ascochyta blight

Figure 12.
Stem lesion symptom and pycnidia caused by Phoma medicaginis

DOWNY MILDEW
(caused by *Peronospora viciae*)

Downy mildew is prevalent in cool, moist seasons, especially in early sown crops. Substantial yield and quality reductions may occur.

Symptoms: Systemic infection: this usually occurs before flowering and causes stunted, distorted plants, which may wither and die. Local infections, usually result from wind or splash dispersed spores, and infection first appears as fluffy-grey mildew on the undersides of lower leaves on plants and the upper sides of the infected leaves have light brown angular blotches.

Pods: High humidity during pod development may lead to yellow blisters on outer pod surfaces and white fluffy growth inside the pods. Seed may be aborted.

Control: The fungus produces resistant spores in diseased tissue. These can survive for a long time in the soil, removal of residues/volunteers and extending intervals between pea crops is recommended. Treat seed with approved fungicides to control seedling infections. Foliar fungicides can be applied to control secondary infections. Some cultivars are resistant to downy mildew, and these can be used in conjunction with cultural controls (tillage and crop rotation) to reduce incidence of this disease.

Figure 13. Downy mildew on the underside of leaves

Figure 14. Downy mildew-infected pods Note the white growth on internal pod surfaces

Figure 15. Downy mildew-infected pods (left) and healthy pods (right)

Figure 16. Plant with systemic infection

POWDERY MILDEW
(caused by *Erysiphe pisi*)

Powdery mildew can occur in most growing seasons, but is usually severe in late sown processing pea crops. However this disease can also be widespread and severe when dry, warm weather conditions, with evening or morning dew, occur early in the growing season. The pathogen overwinters on infected plant debris and alternative hosts.

Symptoms: Initial signs of this fungus are small, white lesions, usually on upper leaf surfaces. Severely infected plants become grey-green to white and all plant surfaces can be affected. Infected tissue may wither and die. Infection can also hasten maturity and cause tainted or bitter flavour to the harvested processing peas.

Control: Pea cultivars resistant to powdery mildew should be used particularly for crops sown for mid and late season harvest. Systemic fungicides and sulphur are available to control the disease in susceptible cultivars. Regular monitoring of crops is recommended as this disease can develop very rapidly in susceptible crops.

Figure 16. A pea leaf with severe powdery mildew

Figure 18. Powdery mildew-affected (left) and healthy (right) pea crop

Figure 19. Pea leaves and pods with severe powdery mildew (left) and healthy leaves and pods (right)

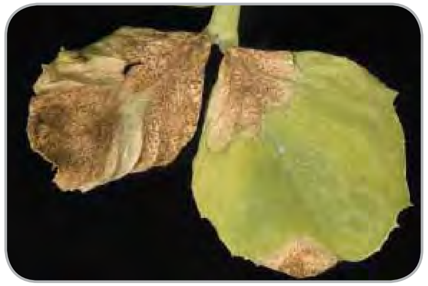
SEPTORIA BLOTCH
(caused by *Septoria pisi*)

Septoria blotch in peas is thought to be of little economic importance in New Zealand. Green leaf area can be reduced quite markedly by the disease; however in warm moist seasons this disease can increase in prevalence. Crops are at higher risk of Septoria blotch in the spring months.

Symptoms: *Septoria pisi* causes light brown, elongate to rounded necrotic blotches which are limited by leaf veins, and the lesions usually have yellow halos. These occur first on lower mature leaves and then spread up the plant. Small brown dots (pycnidia) can be seen within lesions. If the disease is severe, stems and pods can be affected. Mature plants are more resilient to infection although early infection can kill young plants.

Control: Crop rotation of at least two years between pea crops is recommended. Elimination of crop residues and volunteers will reduce inoculum. Late maturing cultivars are more tolerant of the disease than early maturing ones. Foliar fungicide may reduce infection.

Figure 20. Septoria blotch on pea leaves



Figures 21 & 22. Severe Septoria blotch on pea leaves

MINOR FUNGAL DISEASES

BOTRYTIS GREY MOULD
(caused by *Botrytis cinerea*)

Botrytis grey mould can be prevalent during wet, humid seasons, especially if these conditions occur during flowering.

Symptoms: Water soaked lesions appear first and then later develop fuzzy grey masses of spores (conidia). These initially appear on the lower leaves, often starting from the axil of the stipule or from clinging blossom to the pod tip. Mature lesions are greyish and sunken.

Control: Application of foliar fungicides may control infection.

Figure 23. Botrytis (grey mould) on pea pod

Figure 24. Severe Botrytis (grey mould) on pea pod

SCLEROTINIA
(caused by *Sclerotinia sclerotiorum*)

Sclerotinia has a wide host range, including peas. It can be a destructive disease in wet conditions which stimulate excessive vine growth. Too high soil nitrogen level, heavy seeding rates and dense canopy with no air circulation are conducive to the development of this disease.

Symptoms: Symptoms often first appear on stems or leaves that touch the soil surface. Watery lesions develop into fluffy white mycelium, and tissue may appear slimy. Black sclerotia develop within mycelium or inside the stems.

Control: Use clean seed. Rotation can help reduce sclerotia build-up in soil. Preventative fungicide applications may help control the disease.

Figure 25. Sclerotinia damage on pea stem

Figure 26. Sclerotinia damage on pea pods

Figure 27. Sclerotinia lesion on pea pod

ALSO RECORDED IN NEW ZEALAND:
Leaf rust (*Uromyces spp.*) and Fusarium wilt of peas (*Fusarium oxysporum f. sp. pisi* Race 2)

Figure 28. Leaf rust on pea plants

Figure 29. Leaf rust pustule

ROOT ROTS
A complex of soil fungi can cause root rots of peas. These include *Fusarium* sp. especially F. *solani* f. sp*. pisi, Phoma medicaginus* var*. pinodella*, *Rhizoctonia solani* and *Tricocladium* (Thielaviopsis) *basicola* and *Pythium* sp. Root rots can be severe in areas where peas have been grown for a long time and during hot dry seasons with high soil temperatures. Close rotations, compacted soil and low soil fertility may exacerbate root rots.

Symptoms: Reddish-brown streaks coalescing into dark lesions that encircle the roots. Discolouration of vascular tissue. In severe cases, the roots are black and weak and may disintegrate when plants are pulled from the soil. Sudden collapse of seemingly healthy plants in hot dry weather.

Control: Use treated seed, less susceptible cultivars, long rotations between pea crops and avoid root and moisture stress on plants.

Figure 30. Root rot caused by Fusarium solani f. sp. pisi

Figure 31. Root rot caused by Tricocladium (Thielaviopsis) basicola

APHANOMYCES ROOT ROT
(caused by *Aphanomyces euteiches*)

Found in most pea growing areas in New Zealand, *Aphanomyces fungi* can infect crops at all soil temperatures conducive to pea growth, but high soil moisture and warm temperatures can encourage the infection. Cool wet springs followed by dry warm summers particularly favour disease development.

Symptoms: Honey coloured, water soaked lesions on the roots and stem bases are first signs of disease. Plants become stunted, yellow, then may wilt and die. When infected plants are pulled by hand, the root sheaths may slough off in the soil, leaving only the root conductive tissue attached.

Control: Susceptible paddocks can be identified prior to drilling by soil index testing. This measures the relative likelihood of the disease occurring. Soil inoculum may be reduced by long intervals between other host crops such as: clover, lucerne, beans, alfalfa, lupins, lentils and spinach. Susceptible weeds such as field pansy, chickweed and shepherd's purse can also become infected and maintain soil inoculum levels. Peas following brassica crops in the rotation can limit Aphanomyces root rot incidence.

Figure 32. Aphanomyces root rot caused by Aphanomyces euteiches

BACTERIAL DISEASES

Bacterial blight is the only important bacterial disease of peas in New Zealand. Damage by the bacteria *Pseudomonas syringae* and *Pseudomonas viridiflava* may occur occasionally.

BACTERIAL BLIGHT
(caused by *Pseudomonas syringae pv. pisi*)

Bacterial blight is induced by cool, wet weather conditions (made worse by hail damage), especially in early sown crops. The pathogen may be seed-borne.

Symptoms: Lesions usually appear first as water-soaked, glassey angular lesions. Older lesions are papery with light brown centres and dark borders. Pods may become severely infected, with lesions that are roughly circular, watery and sunken. Seeds can become infected via pod infection. Plant growing tips may be killed by blight resulting in irregular maturity.

Control: Certified seed should be free of blight. Physically damaging plants during cool wet weather can encourage infection. Eliminate crop residues. Avoid walking through crops or using machinery, such as rollers, during damp, cool weather since these activities may damage the plants and spread infection. A suitable crop rotation should be practiced to avoid any contact with residue or straw from previous pea crops. The pathogen does not survive in the soil after infected tissue has decomposed.

Figure 33. Bacterial blight symptoms on pea leaves

Figure 34. Bacterial blight symptoms on pea pods

Figure 35. Bacterial blight symptoms on pea plant

DISEASES CAUSED BY VIRUSES

In New Zealand, most of the recorded pea virus diseases are spread by aphid vectors. Aphids may overwinter in lucerne and clover, and on weeds or perennial plants. In spring and autumn, aphid numbers increase rapidly and winged aphids fly to emerging pea crops, carrying with them viruses which may be harboured in overwintering plants.

While incidence of particular viruses may be low, seasonal climatic conditions favourable to aphids (e.g. mild conditions in winter and early spring) have resulted in widespread virus-induced damage to pea crops in some recent growing seasons. Common aphid species found on peas:

PEA APHID
(*Acyrthosiphon pisum*)

Figure 36. Wingless pea aphid

Figure 37. Winged pea aphid

BLUE GREEN LUCERNE APHID
(*Acyrthosiphon kondoi*)

Figure 38. Winged blue green lucerne aphid

GREEN PEACH-APHID
(*Myzus persicae*)

Figure 39. Wingless green peach-aphid

Figure 40. Winged green peach-aphid

POTATO APHID
(*Macrosiphum euphorbiae*)

Figure 41. Wingless potato aphid

Figure 42. Winged potato aphid

Aphid control: Several insecticides are registered for control of aphids on peas. These can be used to reduce infestations and may limit spread of virus diseases within and between crops. Growers should scout crops to see if aphids are present before applying insecticides. Weed control in pasture and wasteland will also minimise transmission of virus diseases from these reservoirs of infection.

ALFALFA MOSAIC VIRUS (AMV)

Symptoms: Plants infected with AMV commonly show necrosis on stems and vein necrosis on upper leaves along with purple areas on pod surfaces, which later become sunken and blackened. Plants turn yellow and collapse. Crop yields are reduced through plant death, the production of small seeds and seeds with brown coat discolorations.

Control: Pea crops should not be sown directly adjacent to lucerne or clover. Weeds may also harbour AMV. Management of lucerne or clover crops by grazing and/or spraying to minimise aphid populations is advisable if peas are to be grown nearby. Insecticide applications may be worthwhile in and around affected crops.

Figures 43, 44 and 45. Alfalfa mosaic virus symptoms on pea plants

CUCUMBER MOSAIC VIRUS (CMV)

This virus will infect peas in a manner similar to AMV. Weeds and lentil crops can be particularly important reservoirs of CMV.

Symptoms: Growing points of plants infected with CMV will wilt and curl, and eventually these plants may die. Stems and petioles of infected plants often have brown streaks, and pods are flattened and turn purple-brown in colour.

Control: Pea crops should not be sown adjacent to high weed populations which act as potential reservoirs of infection. Management of lucerne or clover crops by grazing and/or spraying to minimise aphid populations is advisable if peas are to be grown nearby. Insecticide applications may be worthwhile in and around affected crops.

Figure 46. Cucumber mosaic virus (CMV) symptoms on pea plant

PEA STRAIN OF BEAN YELLOW MOSAIC VIRUS (BYMV)

BYMV (also called pea mosaic virus) is not seed borne and is spread to pea crops from clover (especially red clover), field and broad beans by any of the aphid species associated with these crops in New Zealand. This disease has only been a problem in Hawke’s Bay but may occur occasionally in field peas.

Symptoms: Initial symptoms are the clearing and yellowing of the veins of young leaves. Leaves later become more generally mottled producing distinctive mosaic patterns in susceptible pea cultivars. Infected plants are usually stunted and pale with smaller leaves than normal.

Control: Most cultivars of processing and some field peas currently grown are immune to this virus. Pea crops should not be sown directly adjacent to clover crops. Insecticides to kill aphid vectors and control the spread of virus may be worthwhile in and around affected crops.

Figure 47. Pea strain of bean yellow mosaic virus (BYMV)

PEA SEED-BORNE MOSAIC VIRUS (PSBMV)

This virus has been widespread in past years and can have a seed-borne incidence of up to 80% in badly affected seed lines. The virus is also aphid transmitted.

Symptoms: Recognition of PSbMV in the field is difficult, since plant symptoms are usually very mild. The main symptom is downward rolling of leaf margins and slight clearing of the veins in young leaves. In some seasons, small seeds with distinctive brown staining and "tennis ball" marking (Figure 48) may occur with PSbMV infection.

Control: Sow PSbMV resistant field pea cultivars or seed tested free of PSbMV at the AssureQuality Seed Testing Station, Lincoln. Insecticides to kill aphid vectors and control the spread of virus may be worthwhile in and around affected crops.

Figure 48. "Tennis ball" marking on pea seed caused by pea seed-borne mosaic virus (PSbMV)

Figure 49. Leaf rolling symptom on process pea caused by pea seed-borne mosaic virus (PSbMV)

Figure 50. Seed coat staining and "tennis ball" marking on pea seed caused by pea seed-borne mosaic virus (PSbMV)

TOP YELLOWS VIRUS DISEASES

Top yellows disease is caused by the aphid transmitted viruses Soybean dwarf virus (SDV) (=Subterranean clover red leaf virus) and Beet western yellow virus (BWYV)). The main source of SDV is white clover, BWYV similarly occurs in pastures and particularly in beet, brassicas and weeds.

Symptoms: In susceptible cultivars the viruses cause marked stunting and yellowing of plants, and leaves become rigid and brittle. Shoots frequently proliferate from nodal buds at the base of infected plants, and these plants often succumb to secondary root rots.

Control: Sow resistant or tolerant pea cultivars. Susceptible pea crops should not be sown adjacent to high weed populations or pasture crops which act as potential reservoirs of infection. Systemic insecticides have been shown to be effective in reducing transmission.

Figure 51. Stunting and yellowing of a top yellows - infected plant

ALSO RECORDED IN NEW ZEALAND

Tomato spotted wilt virus

SOIL NUTRIENT ISSUES

MANGANESE DEFICIENCY

Manganese deficiency (marsh spot) is sometimes seen in peaty soils with a pH greater than 6.1. Symptoms include interveinal chlorosis of younger leaves, stunted growth and poor pod set and pod fill due to aborted ovules. The centres of seeds may become necrotic. This disorder can be controlled by applications of manganese at sowing or by foliar applications at first flower.

Figure 52. Marsh spot symptoms on pea seed caused by manganese deficiency

MANGANESE TOXICITY

Manganese toxicity (purple blotch) can occur in some seasons, usually under conditions of low soil pH (below 5.0) and especially on late planted crops, and on heavy soils. Early symptoms include irregular blotches of rust-coloured tissue on the outer margins of the leaves. Later, blotches can appear between the veins, and coalesce and change colour to purple. Plants are stunted, with purple shrivelled foliage at the lower parts of the plant, purple foliage in the middle and chlorotic and green young growth. The disorder can be reduced by liming soil to a pH of 6.0 or more, but in some soils the condition will still appear even at these soil pH levels.

Figure 53. Purple blotch symptoms on pea plants caused by manganese toxicity

Figure 54. Purple blotch symptoms on pea leaves caused by manganese toxicity

NOTES

Table 14. Fungicides and insecticides registered in New Zealand for use on pea crops (source: New Zealand Novachem Agrichemical Manual 2008).
**ChampTM DP is a BioGro certified input for organics 4027 restricted status*

Product	Active Ingredient (a.i.)	% a.i.	Chemical Group	Rate of Application	Withholding Period	Target Disease / Pest
Amistar® WG	Azoxystrobin	50	Strobilurin	250 g/ha in min 200 l water/ha	Garden & process without pods 14days / dry seed peas, dry animal feed peas 35 days	Ascohyta, downy mildew, powdery mildew
Captan 80W	Captan	80	Cyclic imide	7-9 kg/ha & work into upper 10cm of soil or 3-4.5 kg in row at planting	Pre-Em	Root rot & damping off (pythium)
Captan Flo		48		12-15 l/ha & work into upper 10cm soil		
Crop Care Captan WG		80		As Captan 80W		
Crop Care Captan 900WG		90		6.2-8 kg/ha		
Merpan		80		As Captan 80W		
Nordox 75	Copper as Cuprous Oxide	75	Inorganic copper	100 g/100 l water	1 day	Downy mildew & leaf
Oleo 40		65		120 ml/100 l water		spot
Agpro Cupric Hydroxide 350SC	Copper hydroxide	35	Inorganic copper	200-350 ml/100 l water		Downy mildew & leaf spot
Blue Shield® DF		50		150-250 g/100 l water		
ChampTM DP*		37.5		115-150 g /100 l water		
ChampTM Formula 2 Flowable		33.5		130-215 ml/100 l water		
Headland Choice		35		200-350 ml/100 l water		
Kocide 2000DS		35		115-150 g/100 l water		
Kocide® 2000LS		36		115-150 g/100 l water		

Agpro Copper Oxychloride 800WP	Copper oxychloride	50	Inorganic copper	400 g/100 l water	Nil	Downy mildew & leaf spot
Fruitfed Copper Oxychloride		50		3-6 kg/ha		
Headland Copper		24.8		3-6 kg/ha		
No Fungus Copper Oxychloride		50		500 g/100 l water		
Copper Oxychloride 50%WP		50		3-6 kg/ha		
Alto® 100SL	Cyproconazole & n-methyl-2-pyrrolidinone	10 9.6	Triazole	250 ml/ha	14 days	Powdery Mildew
Rubigan® Flo	Fenarimol	12	Pyrimidine	200 ml/ha	14 days	Powdery mildew
Apron ® XL	Metalaxyl-M	35	Phenylamide	100 ml/500 ml water/100 kg seed	Seed Treatment	Downy mildew & damping off
Citara® 200EW	Penconazole	20	Triazole	125-175 ml/ha	14 days	Powdery mildew
Pendant						
Topas® 200EW						
Super Six®	Sulphur	72	Sulphur	110-220 ml	Nil	Powdery mildew
Sufla DF		80		100-200 g/100 l water		
AxisTM	Tebuconazole	25	Triazole	250 ml/ha	14 days	Powdery mildew
Compass®		43		145 ml/ha		
Folicur® 430SC		43		145 ml/ha		
HornetTM 430SC		43		145 ml/ha		
OruisTM		25		250 ml/ha		
MiltekTM	Triadimefon	6.3	Triazole	1 l/ha	14 days	Powdery mildew
CereousTM	Triadimenol	25	Triazole	250 ml/ha	28 days	Powdery mildew
TributeTM SC		37.5		165 ml/ha		
Citadel®	Triadimenol & n-methyl-2-pyrrolidone	25 37.5	Triazole	250 ml/ha	28 days	Powdery mildew
Dimezyl® 40EC	Dimethoate	40	Organo-phosphate	800ml/ha		Aphids
Perfekthion® S		50		650ml/500-1000 l water		
Pirimax 500	Pirimicarb	50	Carbamate	250 g/ha in 200 l water	Crops for human consumption 3 days	Aphids
Pirimor® 50						
Pirimisect						
Prohive						

NOTES

HARVESTING

For seed crops which are weedy, or uneven in ripening, using diquat is an option (don't use glyphosate as a desiccant for peas). Monitor seed moisture content (SMC) to determine when the crop is fit to harvest. Ensure the combine is correctly set up to harvest peas and use a relatively slow drum speed and wide concave to minimise pea cracking/splitting, as this can effect the germination of the following seed line, Figure 55.

Figure 55. The effect of harvest damage on pea germination.

Direct combining at 16-18% SMC is the preferred option for all seed pea types except marrowfats. For marrowfat crops capturing and maintaining seed colour is an important quality aspect and swathing or windrowing is an approach most growers use to achieve colour quality. Cut when SMC is around 50%, windrow, and combine once SMC has reached 16-18%. (Note: cutting at >54% results in small/uneven seed and hard seed). Minimising the time a crop sits on the ground is also important as bleaching and staining may increase with poor weather. Aim to harvest windrowed crops as soon as they are fit.

Vining pea processors typically have a nominal factory capacity, limited usually by the number and size of freezing tunnels. The larger processors generally aim to process peas 24*7 at close to their factory capacity for as many days as it takes them to harvest the total contracted land area. Apart from short routine stoppages to clean and sterilise processing equipment or defrost iced-up tunnels, this continuous processing gives the most efficient deployment of staff and machinery. Harvesting is undertaken with gangs of specialist pea viners operated by the processor or its agent. Because the supply of raw material must match the factory capacity, and because each pea crop has a very short window of optimum maturity, and then must be processed immediately upon harvest, the processor necessarily has to schedule the sequence and timing of harvest, and hence control the sequence and timing of plantings.

Pea maturity is measured by an instrument called a tenderometer which produces a Tenderometer Reading (TR). A representative sample of podded peas is placed in the instrument which measures the force required to crush the peas. NZ process pea crops would mostly be harvested when maturity is between TR 100 and 140. Less than TR 100 is young, tender and sweet but yield is sacrificed. Above TR 140 peas quickly develop starchy and mealy texture and lose sweetness, but yield and processing recovery is maximised. A typical pea crop nearing TR 100 will advance about 10 to 15 TR points per day, depending on the temperature experienced that day, so the processor might only have a three to five day window to harvest each crop from when it reaches a harvestable maturity to when it gets too old. Processors pay a higher price for lower TR peas, and lower price for higher TR peas.

Note - “baby peas” are popular with consumers. These aren’t necessarily crops harvested young. They are the smaller less mature peas from the later-flowering trusses higher up the plant which, during processing, are separated by size from the larger diameter older peas on the plant.

PEA SEED DRYING AND STORAGE

Seed quality needs to be maintained during storage by minimising the rate of deterioration and preventing spoilage by fungi. Pre-harvest, harvest and post-harvest environments influence the storability of seed. In storage, seeds continue to age. Seed ageing is influenced by initial seed condition, temperature, moisture content and storage time. Storing seed at low temperature and relative humidity will minimise loss of seed quality. Safe storage moisture content for peas for a period of one year is 14% moisture content at 63% relative humidity (RH). In general terms, from this moisture content reducing the moisture content (MC) by 1% will double the storage life and reducing the storage temperature by 5°C will double the storage life. Pea seed stored at 20% RH will equilibrate to a moisture content of 7%, at 40% RH to 10.3% MC, and at 60% RH to 13.5% MC.

If peas have been harvested at a higher SMC (>15%) they will need to be dried. The safe drying air temperature will depend on the harvest SMC i.e. if harvest SMC is >20%, then drying air temperature should not exceed 32°C. If harvest SMC is 14-17%, then drying air temperature should not exceed 37°C. Peas are considered to be a slow drying seed and in the time taken to remove 1% of moisture from wheat only 0.4% of the moisture content in peas will have been removed.

Note: Even if SMC is around 15% at harvest, any seed harvested on a hot, clear, sunny day may be 10-12°C hotter than ambient air temperature (because seed absorbs radiant heat). Such seed, if placed immediately into bulk storage, must have its temperature reduced by blowing cool air through it.

- Ensure all storage areas are free from pests and other possible sources of contamination.
- Always handle peas carefully to avoid bruising, cracking or splitting.
- Monitor temperature, SMC and pest status of stored peas regularly so that corrective action can be taken if required.

Further information on drying and storage of peas and other seeds can be found in The Drying and Storage of Grain and Herbage Seed book by Murray Hill; available from FAR.

POST-HARVEST

POST HARVEST SEED QUALITY AND TESTING

There are a number of seed quality aspects that are considered for different pea types, and production contracts may make specific requests of seed quality. These include seed size, colour, uniformity of size and colour, hard-seed, staining, hollow heart, conductivity and germination. Of these conductivity and germination are the most frequent tests conducted.

Conductivity

Seed coat cracking occurs when pea seed is harvested when very dry or the combine settings are incorrect. The seed is tested for seed coat cracking using an electrical conductivity test. This test is used to measure the amount of carbohydrates and inorganic salts lost through the cracks in the seed coat during 24 hours of soaking in de-ionised water.

The greater the amount of these substances that are released from the seed the greater the loss of seed vigour. The results are expressed in micro siemens per gram of seed.

Germination

The germination test is carried out using blotters or sand depending on the disease levels on seed and the harvest conditions for any given season. The germination test records the number of well-developed seedlings on the blotter whereas abnormal seedlings lack well developed roots and plumule.

POST-HARVEST PADDOCK MANAGEMENT

Remove vine trash to minimise disease carry-over. Burning is the most effective method, but may not be economically or environmentally acceptable. Baling will remove most diseased tissue. Ploughing will remove trash but fungal spores can survive on trash buried in the soil. If disease was a problem in the crop, don’t transfer infected straw to other paddocks.

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