Improving field pea yields on farm in Canterbury

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Abstract

Pea yields have declined in New Zealand and many farmers perceive that growing peas is becoming more difficult, more risky and less profitable. A survey of 29 commercial field pea crops (cv. Midichi) was carried out to identify factors that may be contributing to these problems. Paddock history and crop husbandry records were collected and the crops and soils were sampled at different crop growth stages, and at maturity. Potential yields and water balances were calculated for each site. Yields varied from 2.3 to 5.6 t ha^{-1}, and only one crop yielded to its full potential. Most yield loss was due to failure of crops to produce a full leaf canopy, with low harvest indices another main cause of yield loss. Other causes of yield loss were poor soil structure at sowing, high *Aphanomyces* scores, poor plant establishment, and premature senescence. The survey indicated that future research on factors affecting pea yield should be aimed at the establishment and seed fill stages of crop growth.

Additional keywords: soil structure, *Aphanomyces*, plant establishment, ground cover, harvest index.

Introduction

Peas (*Pisum sativum* L.) are an important crop in New Zealand, especially in Canterbury, which is the main cropping region. About 7,000 ha each of field and vining (process) peas are grown each year, with a combined value of over $MZ100M. Pea crops play a vital role in maintaining the biological and economical sustainability of New Zealand's arable industry. They enhance soil fertility and structure, provide breaks for disease control in cereal-based cropping systems, and produce good cash returns if yields are high enough. Despite the crop's importance, pea production is under serious threat. Yields have become more variable, and many farmers perceive that growing peas is becoming more difficult, more risky and less profitable than other arable crops, and this has caused a downturn in the area sown. In the long term this will lead to a reduction in the sustainability of intensive cropping systems in New Zealand as, currently, no other grain legume crops are available which can substitute for the economic and biological sustainability advantages of peas.

Under favourable growing conditions, field pea yields of 7.2 t ha^{-1} were recorded in Canterbury in 2006/07 and 2007/08 (Martin Reid, Cates Grain & Seed Ltd *pers. comm.*). Several extension guides have been written giving recipes to achieve high yields (e.g. Jermyn, 1984; Plant Research (NZ) Ltd., 2002; Foundation for Arable Research, 2002; Pea Industry Development Group, 2008). Based on a modelling approach, 8 t ha^{-1} should be achievable under ideal conditions (Wilson, 2005). However, the current industry average yield is only about 3 t ha^{-1}. In 2003, a group of industry stakeholders formed the Pea Industry Development Group (PIDG) to improve the performance of New Zealand's pea crops. The PIDG developed a programme of research and extension with the goal of devising strategies that growers can use to increase their average pea yield by 25 %, and thus increase total industry revenue by about \$NZ35M annum^{-1}. As part of the programme, a survey of growers' pea crops was carried out in the 2005/06 growing season to determine why yields are so variable and why so many are low.

Materials and Methods

Twenty nine paddocks of the field pea, cv. Midichi, were selected in Canterbury, with a north-south range from Darfield to Waimate, and from the coast to the upper Plains, representing the full geographical spread of pea cropping in the area. The paddocks had a wide range of cropping histories, soil types and management practices. Crop establishment varied from drilling after intensive cultivation to direct drilling. Eighteen of the crops were irrigated.

Field measurements

Each crop was visited and assessed four times during the season. The first visit was soon after crop establishment, at about the three node development stage. A 400 m^2 area was marked out for monitoring. In irrigated crops, a rain gauge was installed in the monitor area to measure rainfall and irrigation applications. A soil sample was collected for an *Aphanomyces* test, and the plant population was counted.

The second visit was at about the first flower stage of crop development to determine the incidence and severity (percentage leaf area infected) of foliar diseases, which were assessed on 50 randomly selected plants.

This disease assessment was repeated at the flat pod stage. Also at this stage, *Aphanomyces* score, root growth, nodule number, plant population, ground cover, crop biomass, lodging and visual scoring of root diseases (Hagedorn, 1984) were all recorded. Soil type and physical and chemical features of soil quality were determined at each site.

Yield was measured at harvest maturity by hand-harvesting five randomly selected 4 m^2 quadrats from the monitor area. Ten plant subsamples were taken from each quadrat for determination of dry weights, yield components and quality assessments. Relevant meteorological data were obtained from an automatic weather station in the vicinity of each site. In addition to this, each farmer provided the cropping history and the crop, rainfall and irrigation record for each monitored paddock.

Modelling of yield estimates

A modelling approach was used to make two estimates of the potential yield of each crop:

1. PY_{Full}: The yield which would have occurred if the crop had developed a full canopy and had no restrictions to growth.
2. PY_{Actual}: The yield which would have occurred given the actual assessed canopy cover in the field, but assuming the crop had no other restrictions to growth.

For each crop, thermal time above a base temperature of 4.5 ^{o}C was calculated using daily maximum and minimum temperatures from the nearest weather station. The mean thermal time for those sites that fell within one standard deviation of the mean of all sites was 657 ^{o}C days from plant emergence to flat pod and 913 ^{o}C days from emergence to crop maturity.

The crop canopy was assumed to expand linearly from zero to full radiation interception over the period from emergence to flat pod, and then remain at 100 % (PY_{Full}) or the actual cover (PY_{Actual}) until maturity. Intercepted radiation, solar radiation from the nearest weather station, and a conversion value of 0.9 g dry matter MJ^{-1} of intercepted radiation were used to calculate daily growth. Potential seed yield was taken to be half the total biomass at maturity.

Two "Yield gaps" (YG) between the potential and actual yields were then calculated:

$$YG_{Full} = PY_{Full} - \text{Actual yield (AY)}$$

$$YG_{Actual} = PY_{Actual} - AY$$

Water balance and water use

A water balance was calculated for each crop using rainfall (R) and Priestley-Taylor potential evapotranspiration (PET) data from the nearest weather station, and irrigation (I) data supplied by the farmer. Potential soil moisture deficit (PSMD) started at zero at establishment and was then calculated each day as:

$$PSMD_{today} = PSMD_{yesterday} + PET - (R + I)$$

A total soil moisture deficit (TSMD) from establishment to maturity was calculated as

$$TSMD = \text{Total PET} - (\text{total I} + \text{total R})$$

Estimated water use was calculated by adding an estimate of available soil water at plant emergence, based on soil depth and any observed impediments to root growth in the soil profile, to the I and R values. Most soils were assumed to have 90 mm of stored plant available soil water in the root zone at establishment, but this was amended to 60 mm for shallow stony soils and 100 mm for heavy deep soils.

Key performance benchmarks

Each crop's failure to reach its potential was assessed in relation to the following practical agronomic criteria, which are suggested key performance benchmarks for Midichi pea crops:

- Established population of at least 80 plants m^{-2}.
- At least 90 % ground cover when the canopy is fully developed.
- Harvest index of at least 45 % at physiological maturity.
- At least 1,600 seed m^{-2} at harvest.
- Mean seed weight at harvest of at least 360 mg (at 12% moisture content).
- About 16 kg ha^{-1} of seed yield mm^{-1} of water used.

Results and Discussion

Rainfall and temperature data for the 2005/06 growing season from Lincoln, Winchmore and Timaru Airport are given in Table 1. Rainfall was below average at Lincoln, average at Winchmore and above average at Timaru Airport. At all three locations, October was cooler than average but, for September and from November onwards, temperatures were generally above average.

Seed yields of the 29 crops were generally poor to moderate, and ranged from 2.3 to 5.6 t ha^{-1} (12% moisture content), with a mean of 4.1 t ha^{-1} (Figure 1). In contrast, potential yields, assuming no limitations to growth and 100 % canopy cover (PY_{Full}), ranged from 4.7 to 7.3 t ha^{-1}, with a mean of 6.4. The range of potential yields resulted from crops sown earlier at cooler locations yielding more than crops sown later at warmer locations, because they had the longest and shortest growth durations respectively. Potential yields were also higher on deeper soils. Only one crop yielded to its full potential (Figure 2).

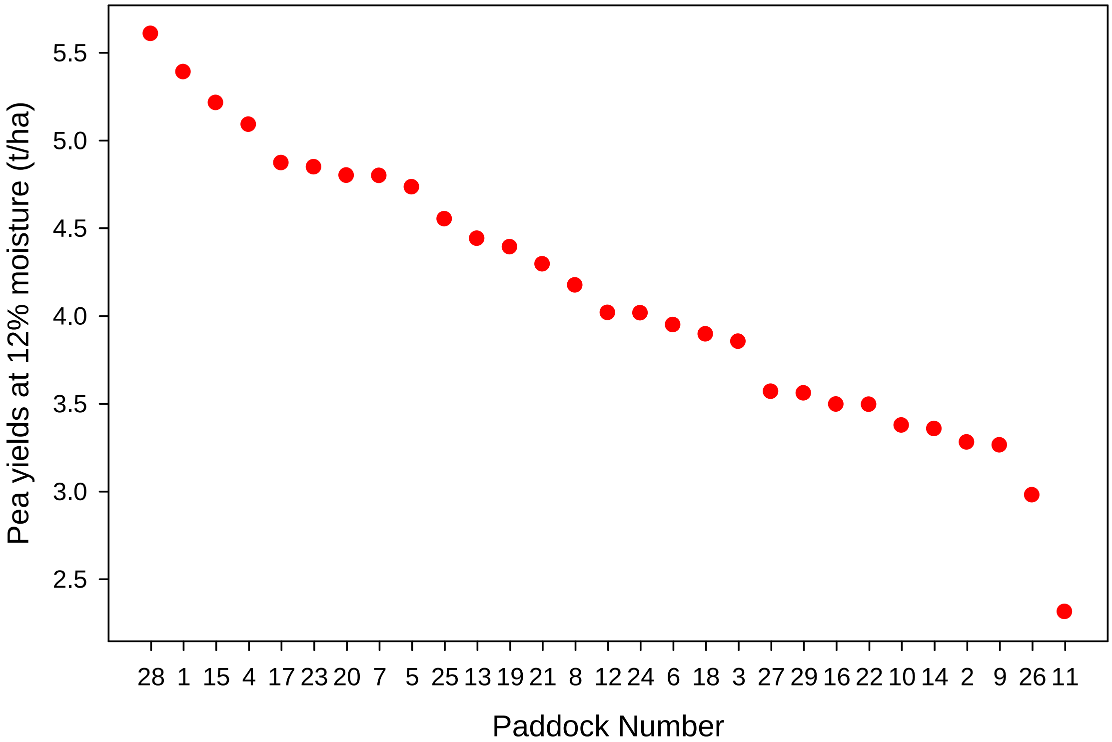

Figure 1: Pea seed yields at 12% moisture content of 29 Midichi pea crops in 2005/06.

PY_{Actual}, calculated using actual ground cover estimates at flat pod, ranged from 3.3 to 6.6 t ha^{-1} (mean 4.7). A number of crops produced close to their potential yields when adjusted for their actual ground cover (Figure 2).

Therefore, on average, 1.7 t ha^{-1} (27 % of potential yield) was lost because of failure to develop a full canopy and intercept all available radiation (PY_{Full} - PY_{Actual}) and a further 0.6 t ha^{-1} (9 %) was lost because of the failure to convert that intercepted radiation into pea seed (PY_{Actual} – AY).

Why didn't most of the farmers' crops yield to their potential? Five major reasons were identified.

First, 83 % of paddocks had a low soil structure condition score, with 75 % having low (< 0.85 mm) aggregate size, and 52 % high penetration resistance scores in the 0 - 15 cm soil layer. Increasing bulk density values from 1.2 to 1.8 g cm^{-3} in the 15 - 30 cm layer, indicating increased compaction and were related to decreased yield (r = -0.5). In established plants, subsoil compaction causes poor root penetration and hence increased susceptibility to drought stress (Dawkins & McGowan 1985, Reid et al. 1987), 83 % had a low soil structural condition score.

Second, *Aphanomyces* scores, both from glasshouse scores of soils sampled at plant establishment and from scores made in the field at the flat pod stage, ranged from 25 to 100 %. There was a moderate, negative, correlation between yield and field *Aphanomyces* score (r = -0.58) (Figure 3), and a moderate positive correlation with crop condition visual score (1 poor, 4 good), at flat pod (r = 0.59). Pea number was also negatively correlated with *Aphanomyces* score. *Aphanomyces euteiches* is a soil borne disease which rots pea roots (Hagedorn, 1984). It is very persistent in soil, and the only control is to avoid planting peas in paddocks with high infection potential. A score of over 50 % indicates that

Aphanomyces could be a problem, and over 70 % indicates that sowing peas is not recommended.

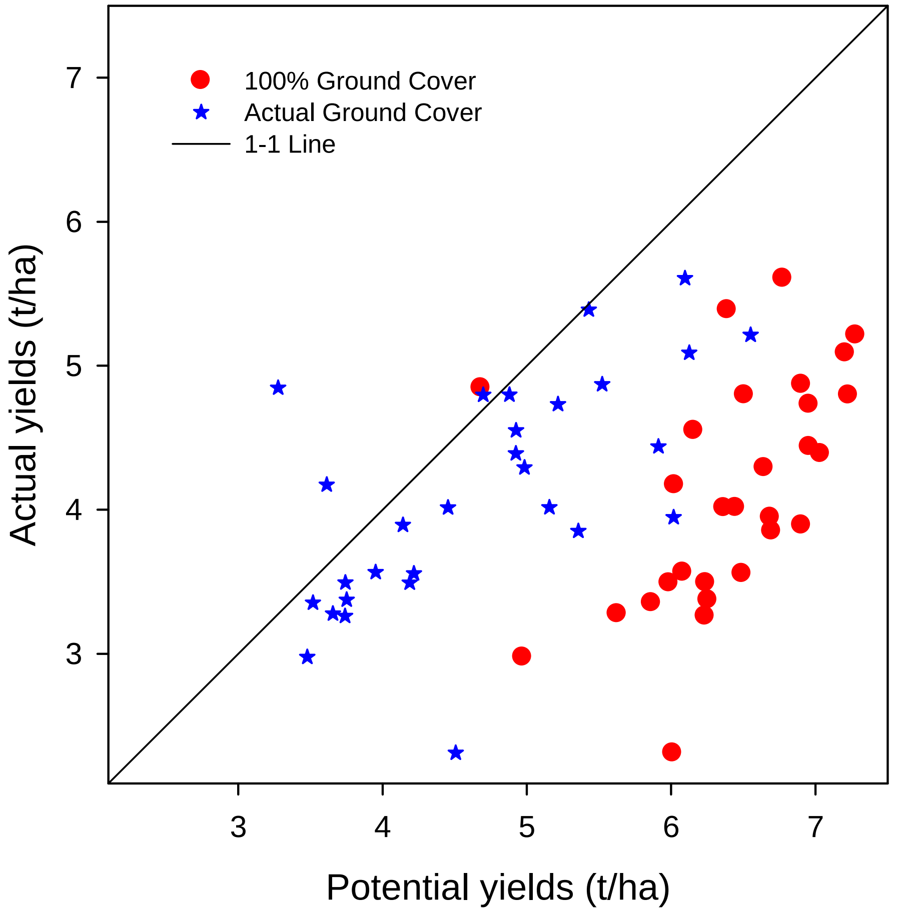

Figure 2: Relationship between actual and (a) potential pea seed yields, with the latter assuming full canopy at flat pod (•) or (b) using actual ground cover at flat pod (×) and no other limitations to growth for 29 Midichi pea crops. Solid line is 1:1 relationship.

Third, the major yield limiting factor was poor plant establishment. Plant populations ranged from 35 to 106 plants m^{-2} (mean 57) with only two crops exceeding the benchmark of 80 plants m^{-2}. Possible causes of this were soil structure (see above) and drilling practice. Unpublished research showed that increased drilling speed reduces the number of seeds sown and established, especially with larger seeded cultivars like Midichi.

Fourth, no crop produced a full leaf canopy. Estimates of ground cover at the flat pod growth stage ranged from 60 to 90 %, (mean 73 %), and so radiation interception, and hence potential yield, was reduced. Yield was negatively correlated with missed radiation interception because of the incomplete canopy (r = -0.53), and there was a moderate positive correlation with ground cover (r = 0.59) (Figure 4). Pea seed number was also correlated with these measurements. Although peas can compensate greatly for low populations (Moot and McNeil, 1995), several of the crops were very uneven, with clumps of plants separated by large gaps. This may explain the poor correlation between plant population and canopy cover among crops.

Table 1. Monthly and total rainfall and mean temperatures from Lincoln, Winchmore and Timaru Airport for the 2005 - 6 season, together with the long-term means (LTM) at each location (MAF 2006).

	Lincoln			
	Rainfall (mm)		Mean temperature (°C)	
Month	05/06	LTM	05/06	LTM
September	39	44	9.9	9.4
October	41	51	11.3	12.3
November	45	50	13.3	13.1
December	33	53	17.2	15.5
January	36	49	17.2	16.0
February	38	42	16.8	16.8
Total (rainfall) or Average (temperature) over season	232	289	14.3	13.9
	Winchmore			
	Rainfall (mm)		Mean Temperature (°C)	
Month	05/06	LTM	05/06	LTM
September	52	50	9.6	8.8
October	62	61	10.6	11.1
November	61	62	13.2	12.7
December	47	64	16.9	14.7
January	70	62	16.7	16.1
February	54	55	16.6	16.0
Total (rainfall) or Average (temperature) over season	346	354	13.9	13.2
	Timaru Airport			
	Rainfall (mm)		Mean temperature (°C)	
Month	05/06	LTM	05/06	LTM
September	21	45	8.8	8.3
October	92	53	10.2	10.9
November	40	53	12.3	11.7
December	69	53	16.2	13.8
January	73	52	15.4	15.5
February	27	48	15.8	15.7
Total (rainfall) or Average (temperature) over season	322	304	13.1	12.7

Finally, many of the crops did not appear to reach physiological maturity. Harvest indices averaged only 28 %, and only one crop reached the benchmark of 45 %. Harvest index increases linearly with thermal time (Lecoeur and Sinclair, 2001) and can be greater than 50 % (Moot and McNeil, 1995). These results indicate that most crops matured prematurely, well before potential seed yield accumulation was completed. This was most likely a result of crop canopies senescing early because of the effects of late water deficit and/or foliar diseases.

Potential soil water deficits ranged from 55 to 326 mm, and so some yields were reduced by water stress, particularly during seed fill. Harvest index is lower in pea crops stressed during seed fill (Martin and Jamieson, 1996). Water balance calculations showed that many of the crops, including irrigated ones, experienced increasingly severe water deficit as the season progressed and that the time of greatest stress was often towards the end of seed fill. Late water stress reduces the ability of irrigated crops to fill the extra, later maturing, pods (Martin and Jamieson, 1996), which explains why pea seed weights were higher in the dryland crops than in irrigated crops.

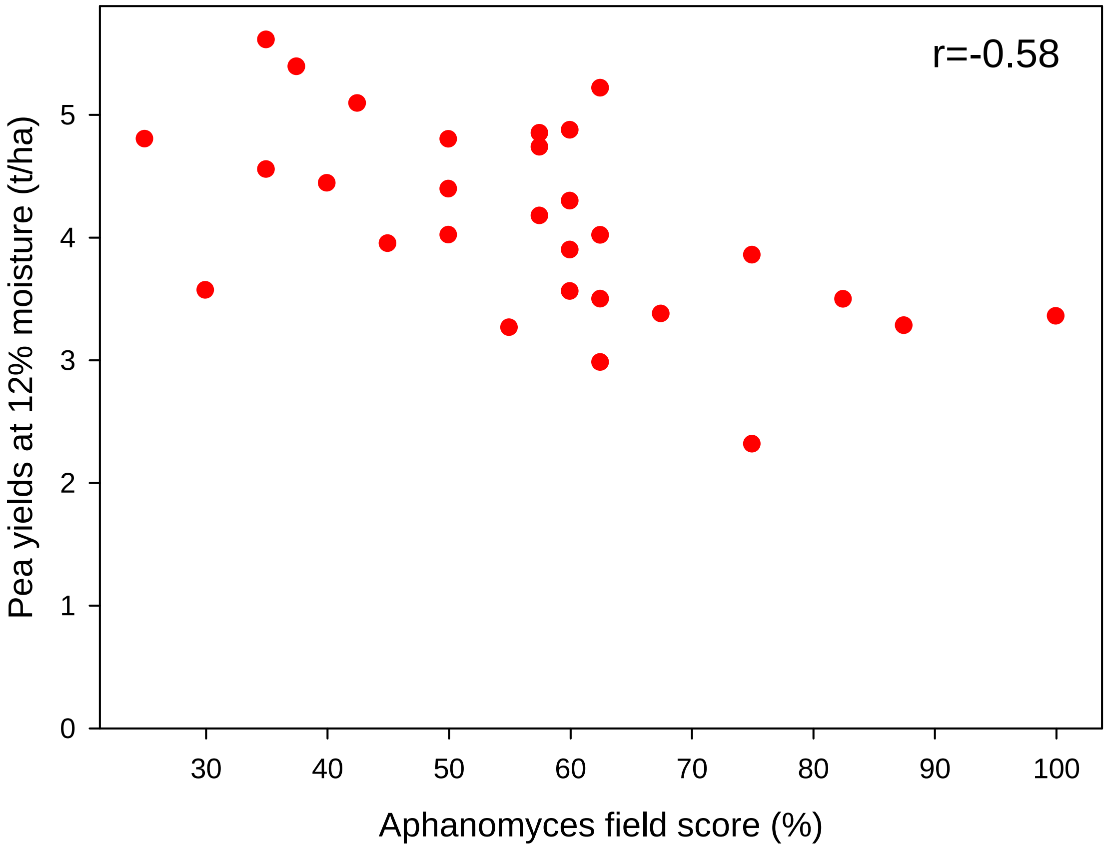

Figure 3: Relationship between pea seed yields at 12% moisture content and *Aphanomyces* field score at crop establishment for 29 Midichi pea crops.

Only two crops had high foliar disease scores at flat pod, but several crops were observed to have a late build up of *Aschochyta* blight at harvest. Two crops were heavily weed infested. Both *Aschochyta* blight and weeds can be controlled by suitable pesticide spray programmes. These observations emphasise the importance of continuing management inputs, especially water and disease control measures, during seed fill to ensure crops realise their full potential.

This approach of using estimates of potential yield based on benchmark values, supported by appropriate soil, plant and management data, was a valuable tool for highlighting where future research and extension effort should be directed. Some of the problems identified by the survey reinforced existing extension messages (e.g. soil testing for *Aphanomyces*). Others could benefit from more research (e.g. crop establishment).

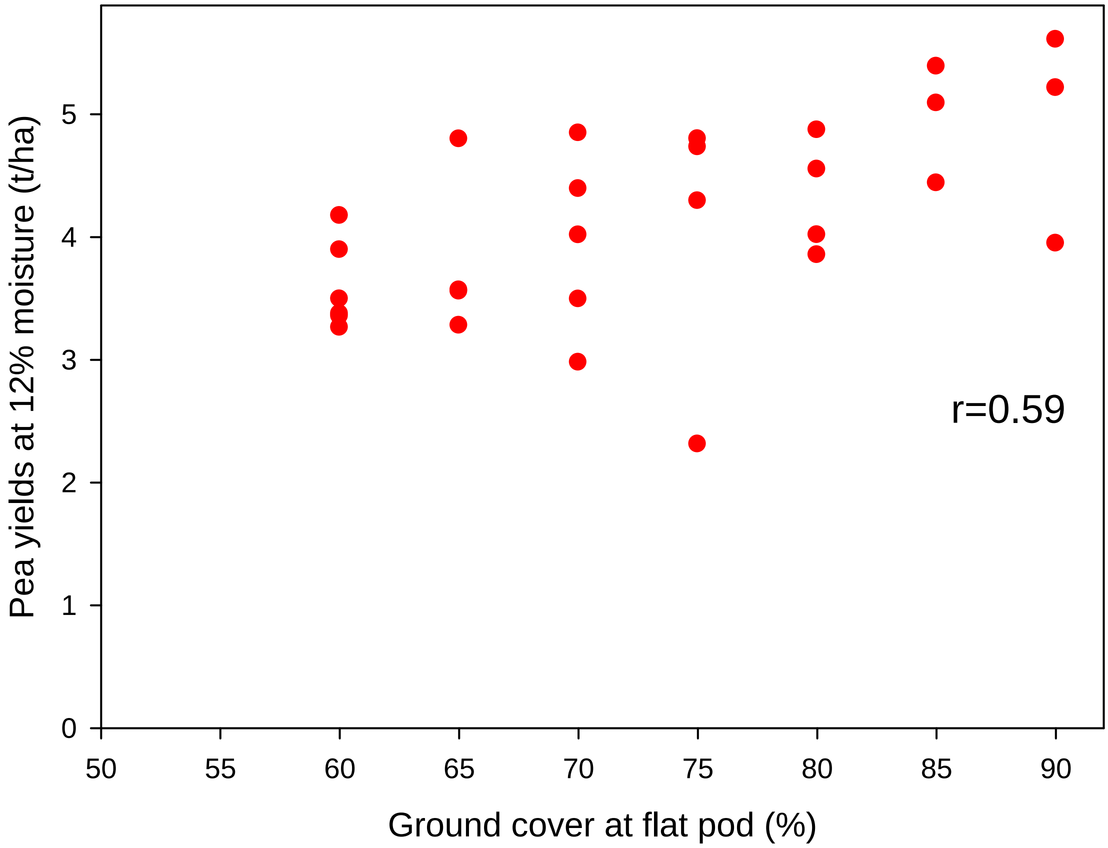

Figure 4: Relationship between pea seed yields at 12 % moisture content and ground cover at the flat pod stage for 29 Midichi pea crops.

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