Effect of population density on within canopy environment and seed vigour in garden pea (*Pisum sativum* L.)

A. G. Castillo[1], J. G. Hampton and P. Coolbear

Seed Technology Centre, Massey University, Palmerston North
[1] University of Southern Mindanao, Kabacan, Cotabato, Philippines

Abstract

In garden pea (*Pisum sativum* L.) grown for seed, plant populations of 50, 100 and 200 plants/m^2 had no significant effect on seed germination of cvs. Pania and Princess. However as population density increased, the incidence of hollow heart increased in both cultivars. Hollow heart was lowest at 100 plants/m^2 in cv. Pania, but did not differ between 50 and 100 plants/m^2 in cv. Princess. Hollow heart was greatest in seeds from pods at the bottom of the canopy at the highest plant population. Conductivity also increased with increasing population density in cv. Pania, but did not differ with population density in cv. Princess. For all populations, conductivity was highest in seeds from pods at the top of the canopy. Within the canopy, temperature at the third podding truss increased with increasing population density in the 10 days prior to seed harvest, the differences between 50 and 200 plants/m^2 ranging from 1-5°C, and respectively averaging 1.3° and 3.8°C greater than air temperature in cv. Pania and -0.8 and 3.1°C greater than air temperature in cv. Princess. Temperature of the bottom pods was greater than air temperature by 2-4°C depending upon population. Relative humidity within the canopy also increased as population density increased. The relationship between growing environment and seed vigour in garden peas is briefly discussed.

Additional key words: *conductivity, hollow heart, germination, relative humidity, temperature.*

Introduction

Most agronomic studies of garden pea (*Pisum sativum* L.) seed crops have been concerned primarily with seed yield (e.g., White and Anderson, 1974) and seed quality as determined by germination testing. However other seed quality factors, particularly seed vigour, are important in garden peas. The vigour status of a seed lot can determine the plant population density achieved, and hence the seed yield (Hampton and Scott, 1982). Pea seed vigour can be decreased by harvest damage (Gane *et al.*, 1984; Castillo *et al.*, 1992), but it is also known that the environment can be detrimental to the development of high vigour seed (Perry, 1980), particularly because of the influence of temperature (Halligan, 1986) and humidity (Delouche, 1980). This study was conducted to examine the effect of one management factor, plant density, on the within-canopy environment and its interactions with pea seed vigour.

Materials and Methods

Field

A field experiment was conducted at Massey University, Palmerston North (40°S, 175°E) in the 1989/90 season. The soil type was an Ohakea silt loam, classified as an aeric fragiaqualf (gleyed yellow-grey earth). In late September 1989, the existing ryegrass-white clover pasture was ploughed and a seed-bed prepared (Castillo, 1992). Superphosphate (0-9-0-12) was applied at 250 kg/ha prior to sowing. Seeds of garden pea cvs. Pania and Princess were supplied by Challenge Seeds NZ Ltd.

Treatments were three plant population densities (50, 100, 200 plants/m^2), designed to represent the recommended population density (Stoker, 1975) and half and double that population. Each treatment was replicated four times for each cultivar in a randomised complete block design. Plot size was 2 x 8m with a 1m border between plots. Seeds were sown by cone seeder (Seedmatic 6, Wintersteiger, Austria) on 3 November 1989 at a depth of 3 cm and with 20 cm row spacings. The target populations were achieved by sowing at 125, 250 and 500 kg seed/ha, giving approximate intra row widths of 10, 5 and 2.5 cm between seeds respectively. Fourteen days after sowing, MCPB at 1.2 kg a.i./ha (3 litres in 200 litres water/ha) was applied to control broad leaf weeds. Occasional plants of white clover were hand removed. Within and above canopy temperature was recorded for each plot by means of two thermometers sited at the third podding truss and 20 cm above the crop canopy. Temperature readings were taken daily between 10.00 am to 4.00 pm at one hourly intervals, beginning 10 days before harvest. Seed moisture content was assessed every two days from 20 days after flowering until maturity (Castillo *et al.*, 1992) using the internationally standardised method (ISTA 1985).

Seeds were hand harvested at 15% seed moisture content by removing all plants from within a randomly chosen 1 x 2m area of each plot (but excluding border rows and 1m from the end of each plot), and removing pods by hand from these plants. Pods were divided into top (distal end), bottom (first podding truss) and middle (all other pods) depending on their position on the plant. Seeds were then hand shelled and warm-air dried to 12% seed moisture content (Castillo *et al.*, 1992).

Seed quality was determined using internationally accepted (ISTA, 1985) or recommended (ISTA, 1987) methods. Germination was assessed using the between-paper method with four replicates of 50 seeds/treatment. Hollow heart incidence was obtained by bisecting seeds which had produced normal seedlings in the germination test (Hampton and Scott, 1982). Seed leachate conductivity was recorded from four weighed replicates of 50 seeds soaked in 250ml de-ionised water at 20°C for 24 h.

Within canopy environment

Because appropriate equipment for the accurate recording of the within-canopy environment could not be used at the field site, a small parallel experiment was conducted in the same season at a site adjacent to a power supply. Soil type was once again an Ohakea silt loam, but with the addition of 50 kg/m^2 potting mix (Smith Soil Industries, Auckland) incorporated to a depth of 15 cm. Seeds of cv. Princess were hand sown on 5 November 1989 at two seeds per position in six rows 20 cm apart per plot. Plot size was 1 x 2 m. Intra-row spacings were 10, 5 and 2.5 cm, replicated three times in randomly assigned plots. After emergence each sowing site was thinned to one plant, producing population densities equivalent to 50, 100, and 200 plants/m^2. Plots were separated by three rows (60 cm) of peas at 100 plants/m^2 and the trial site bordered by five rows (1 m)

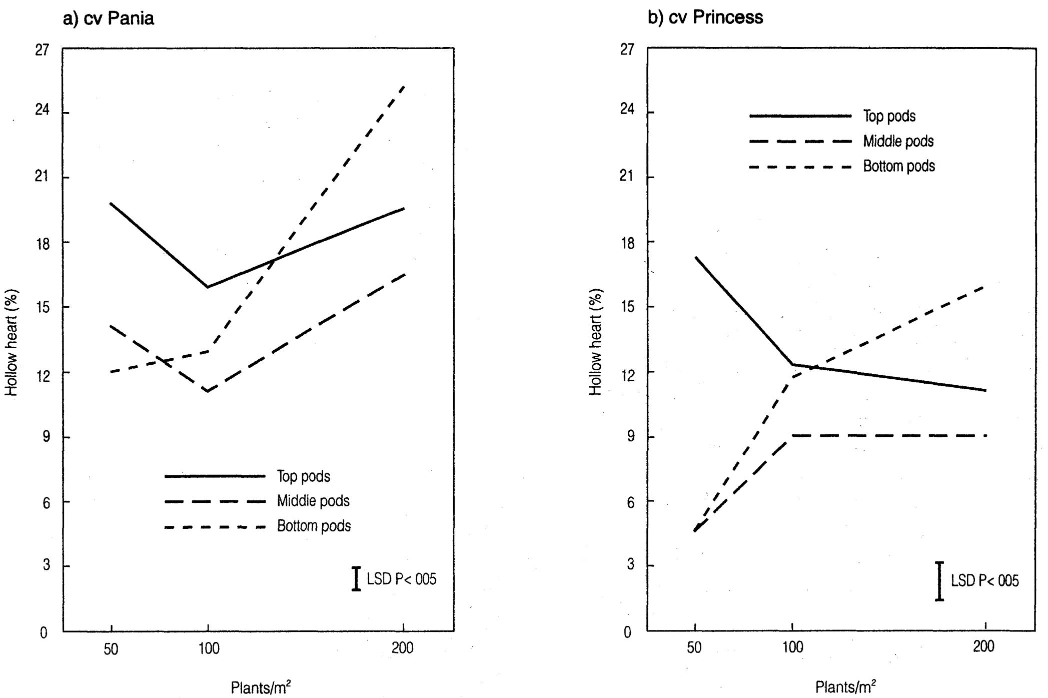

Figure 1. The effect of plant population density and pod position within the canopy on the incidence of hollow heart in seed of garden pea cvs. Pania and Princess.

of peas also at 100 plants/m^2.

Relative humidity within the canopy of one randomly chosen replicate of each treatment was monitored at hourly intervals from 9.00 am to 5.00 pm each day from 20 days after pod setting until maturity by means of a data logger with automatic print out (Current Monitor, Measuremeter II, Anologic AN25M00, Electric Measurement and Control Ltd, Auckland). One probe per plot was set permanently beside the third podding truss at a randomly chosen site between the third and fourth rows. Temperature above and in different parts of the canopy was monitored using a multipoint recorder (Honeywell Versaprint Multipoint Recorder, Yametake, Model J153X89C-52). For one randomly chosen plot from each treatment four temperature probes were located close to the top, middle and bottom pods respectively, and 20 cm above the canopy.

Peas were harvested at 15% seed moisture content, dried to 12% seed moisture content and quality tested as previously described. However, because of a shortage of seeds, conductivity was not recorded.

This trial was repeated in the 1990/91 season using cv. Pania sown on 10 December 1990 and following the same methodology as described for cv. Princess.

Results

Field

Actual population densities recorded were 40, 92 and 185 plants/m^2 for cv. Pania and 45, 95 and 190 plants/m^2 for cv. Princess. As these were close to the target densities they continue to be referred to as 50, 100 and 200 plants/m^2.

Germination did not differ among population densities or pod positions for either cultivar (Castillo, 1992). Mean hollow heart levels increased from 15.6% to 20.2% for cv. Pania and from 9.0% to 12.7% for cv. Princess as population density increased from 50 to 200 plants/m^2,

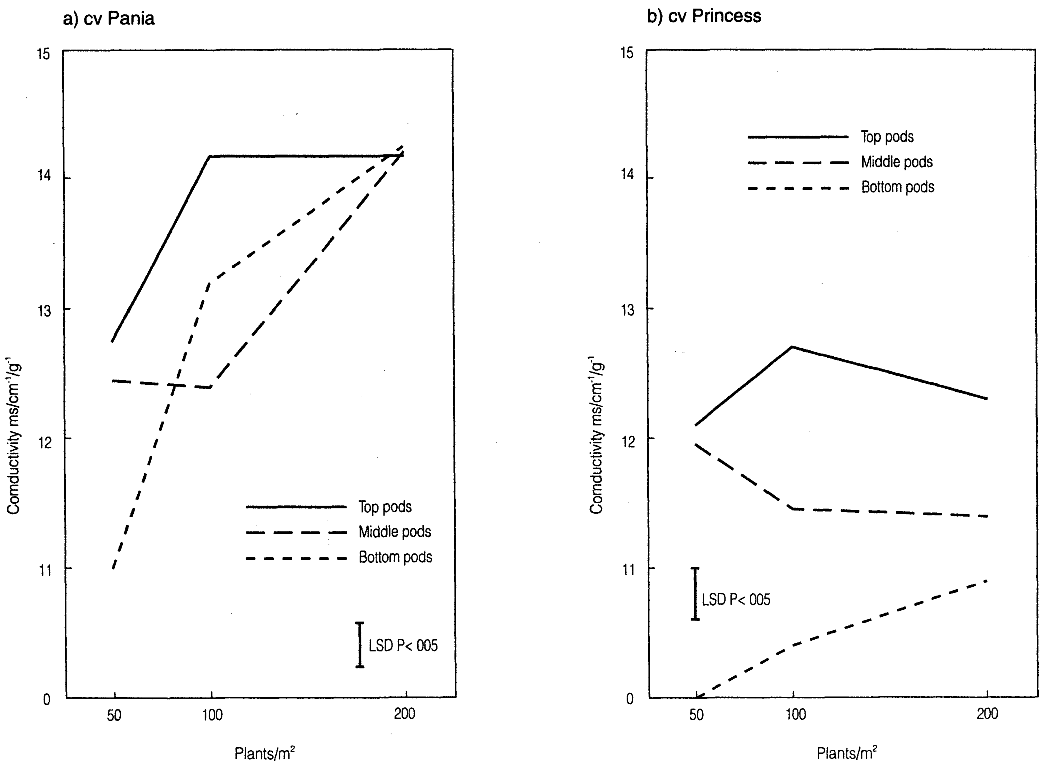

Figure 2. The effect of plant population density and pod position within the canopy on the conductivity of seed of garden pea cvs. Pania and Princess.

but responses differed with pod positions and cultivar (Fig. 1a, 1b). For seeds from bottom pods, hollow heart incidence was lowest at 50 plants/m^2 and significantly higher at 200 plants/m^2 in both cultivars. For top pods, hollow heart was lowest at 100 plants/m^2 for cv. Pania, and did not differ between 100 and 200 plants/m^2 for cv. Princess, but for both cultivars was greater at 50 plants/m^2 than at 100 plants/m^2. Hollow heart of seeds from middle pods was significantly lower than that of seeds from top pods at all three densities in both cultivars, and was greater at 200 plants/m^2 than 50 plants/m^2 in both cultivars. Seed conductivity increased as population density increased in cv. Pania (Fig. 2a) but this response only occurred with seed from the bottom pods in cv. Princess (Fig. 2b). At 100 plants/m^2 seeds from top pods had a greater conductivity than those of seeds from both other pod positions in cv. Pania and Princess, while at 50 plants/m^2, conductivity of seeds from top and middle pods was significantly greater than that of seeds from bottom pods in both cultivars.

Within the canopy, temperature differed depending on plant population density (Fig. 3a,3b) although differences from the air temperature and among populations were not always significant. However in both cultivars temperature was highest at 200 plants/m^2 and usually lowest at 50 plants/m^2, with the differences normally ranging from 1-5°C. Ten day average 1pm temperature was 3.8°C and 3.1°C greater than air temperature at 200 plants/m^2, and 1.3 and -0.8°C at 50 plants/m^2 for cv. Pania and Princess respectively (Fig. 3a, 3b).

Within canopy environment

For cv. Princess in 1990 and cv. Pania in 1991, population density had no significant effect on seed germination, but hollow heart incidence followed a trend similar to that which occurred in the field, i.e., at 50 plants/m^2, hollow heart was greatest in seeds from top pods (10.5% for cv. Princess and 16.5% for cv. Pania) and at 200 plants/m^2, greatest in seeds from bottom pods (13.5% for cv. Princess and 21.5% for cv. Pania). As

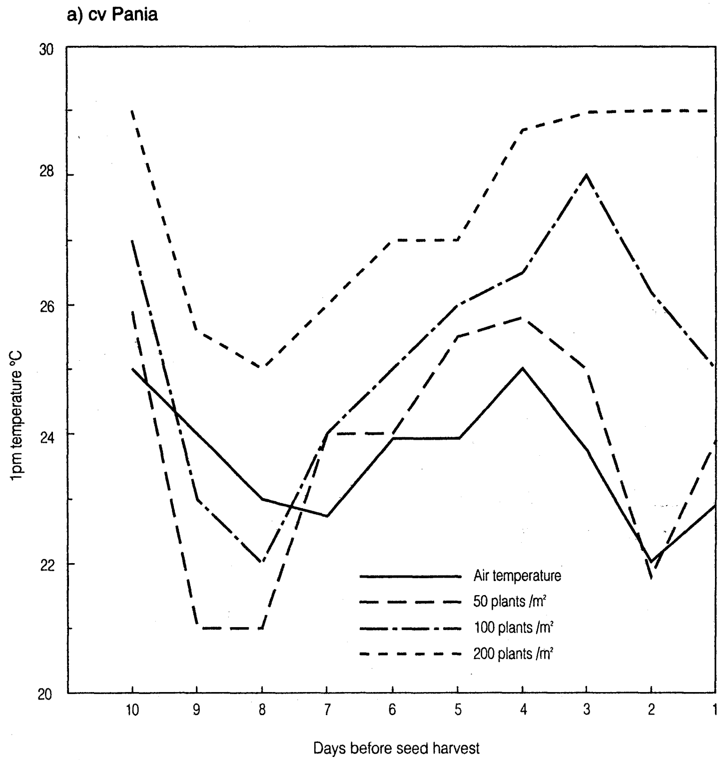

Figure 3. The effect of plant population density on 1pm temperature at the third podding truss for the 10 days prior to seed harvest in garden peas grown in the field. a) cv. Pania.

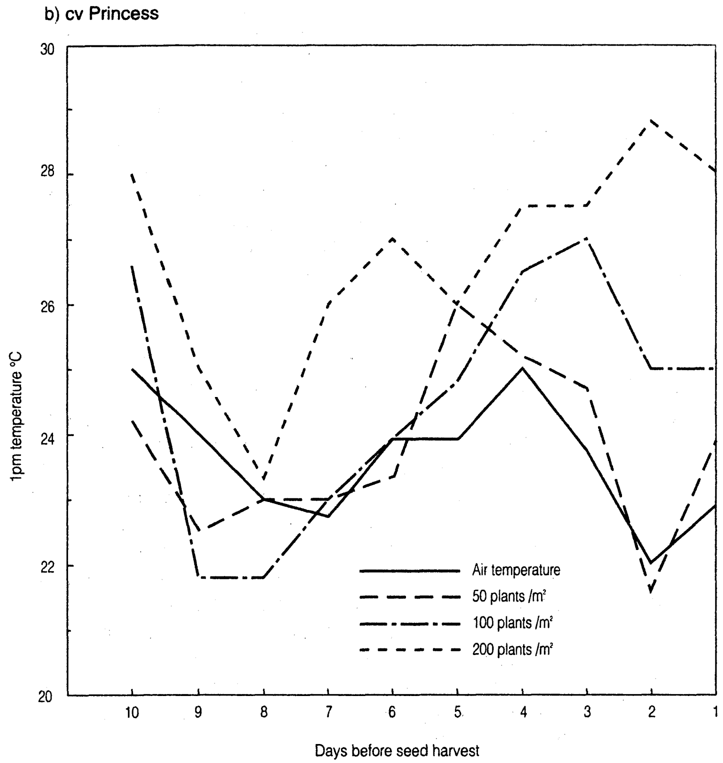

Figure 3. b) cv. Princess.

with the field responses, hollow heart increased in both cultivars as plant population density increased (Castillo, 1992).

For each of the 10 days prior to harvest of cv. Princess in 1990, within canopy temperature was from 1-4°C greater at 200 plants/m^2 than at 50 plants/m^2 (Fig. 4). The average temperature for the 10 days was 2.4°C greater than air temperature at the former and 0.7°C greater than air temperature at the latter population. A similar result occurred for cv. Pania in 1991 (Castillo, 1992). Temperature also differed with pod position. For example in cv. Princess, temperature at the bottom pods for all three population densities was greater than the air temperature

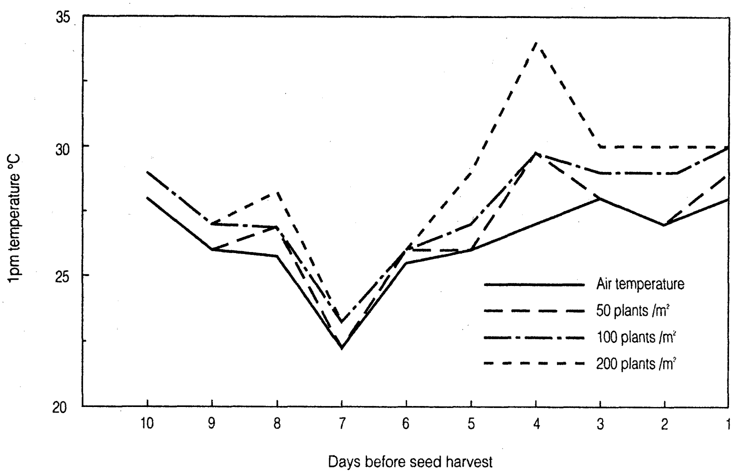

Figure 4. The effect of plant population density on 1pm temperature at the third podding truss for the 10 days prior to seed harvest in garden pea cv. Princess in 1990.

(by 2.2 - 4.3°C), but did not differ with population. Temperature at the top pods did not differ from air temperature, while that of the middle pods at 200 plants/m^2 was greater (Table 1). Relative humidity within the canopy was greater than that of the air for cv. Princess in 1990 and cv. Pania in 1991 (Table 2) at 10 and 5 days prior to harvest, but was sometimes lower than air humidity one day before harvest. Differences from the air humidity varied with plant population density, with humidity tending to increase as population density increased, although differences between 50 and 100 plants/m^2 were small.

Table 1. The effect of plant population density and pod position within the canopy on 1pm temperature at each pod position in garden pea cv. Princess eight days before seed harvest. Air temperature at 1pm = 26.9°C.

	Temperature (°C) at each pod position		
Plants/m^2	Top	Middle	Bottom
50	26.8	26.9	29.1
100	26.7	28.1	30.0
200	26.9	29.0	31.2

Table 2. Effect of plant population density on 1pm relative humidity at the third podding truss in garden pea cv. Princess (1990) and cv. Pania (1991).

	Relative humidity (%) at 10, 5 and 1 days before seed harvest					
	cv. Princess			**cv. Pania**		
Plants/m^2	10	5	1	10	5	1
50	40.1	50.0	37.6	52.7	87.6	44.1
100	42.4	50.1	39.4	54.5	90.2	45.2
200	49.6	74.6	50.1	60.6	100.0	51.2
air[1]	38.6	49.9	45.6	35.0	90.4	58.0

[1] monitored at 20cm above the crop canopy

Discussion

The environment during seed development is a major determinant of seed quality (Delouche, 1980), particularly seed vigour. In garden peas in New Zealand, season, region of production, location of the crop within a district, position of the plant within the field and time of sowing have all been shown to adversely affect seed vigour as determined by the incidence of hollow heart and the conductivity of seed lots (Hampton and Scott, 1982; Hampton, 1984; Castillo *et al.*, 1994). The within-crop environment can also have a significant effect on seed vigour, as has been demonstrated for soybean (Adam *et al.*, 1989) and now garden pea.

Halligan (1986) found that exposure of developing pea seeds to mean day/night temperatures of 25°C or over induced hollow heart, and that the incidence increased with the length of exposure to high temperature. Hollow heart incidence increased as population density increased and at 200 plants/m^2, was highest in seeds from bottom pods. In the 10 days prior to seed harvest, average day/night temperatures exceeded 25°C for five out of the 10 days (Castillo, 1992). The 1pm temperature at all pod positions exceeded 25°C on 9/10 days (e.g., Table 1 and Castillo, 1992) but was always greatest at the bottom pod position. Perry and Harrison (1973) further showed that temperature inside the pod exceeds the within canopy temperature.

The conductivity of pea seeds is a measure of physiological deterioration, indicating the integrity of cell membranes (Powell, 1988). Rapid drying of seed induced by high temperature and deterioration induced by high humidity can lead to damaged membranes and hence increased conductivity (Perry, 1980). Conductivity was greater in cv. Pania than cv. Princess, and only in the former was there a significant conductivity response to increasing population. This may have been an effect of the difference in morphology of the two cultivars, Princess being a relatively tall branching cultivar with greater leaf cover than the more compact and erect Pania, and within canopy temperature and relative humidity was usually higher in cv. Pania than cv. Princess (Castillo, 1992; Table 2). However in both cultivars, but more particularly cv. Princess, conductivity was highest in seeds from pods at the top of the canopy and lowest in seeds from pods at the bottom of the canopy. This is in contrast to the results reported from soybean by Adam *et al.* (1989), who found no effect of pod position on soybean seed conductivity, although for other vigour parameters, top pod seeds were considered superior to bottom pod seeds. Why pea seed conductivity was greater from top pods is not clear, but a possible explanation may be related to the stage of seed development at harvest. Although the whole crop seed moisture content was 15% at harvest, actual seed moisture contents for seeds from top, middle and bottom pods were 20%, 16% and 12% respectively (Castillo, 1992). Conductivity is known to decrease as pea seeds mature (Bedford and Matthews, 1975; Castillo *et al.*, 1992), which could explain the result, even though when tested, all seeds were at 12% seed moisture content. A second possibility is that at harvest, only seeds from top and middle pods required artificial drying and damage to cell membranes may have occurred in the drying process (Hampton, 1992). A further environmental explanation is that in the field, temperature at the base of the crop canopy was slower to warm up each day than that at the top of the canopy (Castillo, 1992) and thus seeds from pods at the top of the crop received a greater time per day at the higher temperature. This explanation however, contradicts the assumed hollow heart response. It is evident that the exact response of pea seeds to the environment requires further detailed investigation, including physiological studies of hollow heart development and cell membrane deterioration.

Conclusions

Scott *et al.* (1991) recently concluded that the current recommendation of a population density of around 100-110 plants/m^2 was suitable for a wide range of New Zealand pea cultivars. Although both hollow heart and conductivity were lowest at a population density of 50 plants/m^2 (i.e., seed vigour was greater at this density), differences between the vigour status of seeds produced from a density of 50 and 100 plants/m^2 were not always significant. Also, because 50 plants/m^2 can limit seed yield (Scott *et al.*, 1991), a population density of around 100 plants/m^2 could be considered suitable for producing optimal yields of seed of good quality. Certainly increasing plant population density above this level would increase the risk of producing seed of lower vigour because of the fact that developing seeds would be subjected to higher within canopy temperatures and humidity. However simply achieving this population density does not ensure high vigour seed, as seed vigour can be reduced by other management factors such as time of sowing (Castillo *et al.*, 1994), time and method of harvest (Castillo *et al.*, 1992) and finally, the environment.

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References

Adam, N.M., McDonald, M.B. Jr and Henderlong, P.R. 1989. The influence of seed position, planting and harvesting dates on soybean seed quality. *Seed Science and Technology* ***17***, 143-153.

Bedford, L.V. and Matthews, S. 1975. The effect of seed age at harvest on the germinability and quality of heat dried seed peas. *Seed Science and Technology* ***2***, 323-335.

Castillo, A.G. 1992. A study of production factors affecting seed vigour in garden peas (*Pisum sativum* L.) and the relationships between vigour tests and seed lot field and storage performance. PhD Thesis, Massey University, Palmerston North.

Castillo, A.G., Hampton, J.G. and Coolbear, P. 1992. Effect of time and method of harvest on seed vigour in garden peas (*Pisum sativum* L.). *Journal of Applied Seed Production* ***10***, 31-36.

Castillo, A.G.; Hampton, J.G. and Coolbear P. 1994. The effect of sowing date and harvest timing on seed vigour in garden pea (*Pisum sativum* L.). *New Zealand Journal of Crop and Horticultural Science* ***22***, 91-96.

Delouche, J.C. 1980. Environmental effects on seed development and seed quality. *HortScience* ***15***, 775-780.

Gane, A.J., Biddle, A.J., Knott, C.M. and Eagle, D.J. 1984. The PGRO Pea Growing Handbook. Processors and Growers Research Organisation, Peterborough, England, 242p.

Halligan, E.A. 1986. The effect of elevated temperatures and their duration on the incidence of hollow heart in pea seeds. *Annals of Applied Biology* ***109***, 619-625.

Hampton, J.G. 1984. Pea seed vigour. *In* Annual Report, Official Seed Testing Station (eds. J.G. Hampton and D.J. Scott), pp. 40-47, Ministry of Agriculture and Fisheries, Palmerston North.

Hampton, J.G. 1992. Prolonging seed quality. *Proceedings of the 4th Australian Seed Research Conference*, 181-194.

Hampton, J.G. and Scott, D.J. 1982. Effect of seed vigour on garden pea production. *New Zealand Journal of Agricultural Research,* ***25***, 289-294.

ISTA, 1985. International Rules for Seed Testing. *Seed Science and Technology* ***13***, 300-520.

ISTA, 1987. Handbook of Vigour Test Methods. Second Edition. International Seed Testing Association, Zurich, Switzerland. 72 pp.

Perry, D.A. 1980. The concept of seed vigour and its relevance to seed production techniques. *In* Seed Production (ed. P.D. Hebblethwaite), pp. 585-591, Butterworths, London.

Perry, D.A. and Harrison, J.G. 1973. Causes and development of hollow heart in pea seed. *Annals of Applied Biology* ***73***, 93-101.

Powell, A.A. 1988. Seed vigour and field establishment. *Advances in Research and Technology of Seeds* ***11***, 29-61.

Scott, R.E., Wilson, D.R. and Goulden, D.S. 1991. Influence of plant population on yields of vining pea cultivars with contrasting seed sizes. *Proceedings Agronomy Society of New Zealand* ***21***, 13-18.

Stoker, R. 1975. Effect of plant population on yield of garden peas under different moisture regimes. *New Zealand Journal of Experimental Agriculture* ***3***, 333-337.

White, J.G.H. and Anderson, J.A.D. 1974. Yield of green peas. I. Responses to variation in plant density and spatial arrangement. *New Zealand Journal of Experimental Agriculture* ***2***, 159-164.