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Studies on the Effects of Pod Position on the Mother Plant and Sowing Density on Flowering, Pod Production, Seed Yield, Yield Components and Viability (Germination) of Pea Seeds

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Abstract: Studies were provided evidence that as density of plant increased seed yield decreased and number of pods per plant, number of seeds per plant, number of seeds per pod, seed weight per plant and 100 seed weight all decreased. High density also produced the poorest quality pea seeds. There were no differences in germination percentage of the seeds produced from the main stem. However, the seeds produced from the branches showed a variation in germination. The germination percentage was similar in the lower nodes but in the upper nodes of the branches showed a lower germination percentage.

Key words: Peas, sowing density, pod, seed yield, germination

Introduction

The heterogeneity observed within commercial seeds may be due to inter or intra plant variation. Cavers and Harper (1966) observed in *Rumex* spp., considerable differences in germination and dormancy characteristics between seeds harvested from different plants grown in the same environment, between inflorescences on the same plant and between different positions of the same inflorescence. The effects of seed position have also been demonstrated in carrot (Borthwick, 1931; Hawthorn *et al.*, 1962; Shevtsova and Koral, 1977; Jacobsohn and Globerson, 1980) where the primary umbels produced heavier seeds with higher germinability than did tertiary umbels. Observations on broccoli (*Brassica oleracea* L.) (Baranauskiene, 1977), celery (*Apium graveolens* L.) (Thomas *et al.*, 1979) and lettuce (Smith *et al.*, 1973) have all shown that seed position may affect seed yield and quality. Austin and Longden (1965) showed that variation in seed weight of peas arose from differences between plants, or between pods on a plant, or within a pod. The results showed that about 87% of the total variability in seed weight arose from the variability between plants, 10% was due to positional effects of the pods on the plant and only 3% was due to variation within pods.

Sowing density has been shown to have large effects on the growth and yield of many crops, including peas. Some studies have shown that yield generally increases with increasing plant density {Baswana and Saharan, 1993 (garden pea); Dwivedi *et al.*, 1998; Auskalnis and Dovydaitis, 1998 (pea)}. Other workers found that yield generally increases with increasing plant density until an optimum plant density is reached and then declines as plant density is increased further {Brathwaite, 1982 (Bodie bean); Townley and Wright, 1994 (field pea); Jovaisiene *et al.*, 1998 (pea)}. This study showed the results of the experiments performed in glasshouse and laboratories to investigate the effects of pod position on the mother plant and sowing density on seed yield, yield components and quality (germination) of pea seeds. This paper also studies the relationship between node position and days from sowing to flowering, sowing to maturity and flowering to maturity. The individual pots were considered as replicates.

Materials and Methods

The experiments was conducted in a glasshouse and laboratories at the Henfaes Research Centre, University of Wales, Bangor, United Kingdom. Top soil was collected from an agricultural field, sieved and 48 pots of 20 cm diameter were filled. Twenty four pots were placed close together so that centre to centre distance was 20 cm. A second series of 24 pots were prepared and placed spaced so that centre to centre distance was 40 cm. Three seeds were sown per pot. Fertilizer 50 kg P_2O_5 ha^{-1} and 50 kg K_2O ha^{-1} were applied as a basal dose in the form of compound fertilizer (0-24-24). The pea variety was Baccara, which is a normal leafed variety and collected from John Turner Seeds, Cambridge, UK.

When the seeds germinated twenty eight days later the plants were thinned to leave one plant per pot. All the plants were grown under the same environmental conditions in an unheated glasshouse. The plants were watered as required. However, when the pods were starting to show signs of ripening (yellowing) watering

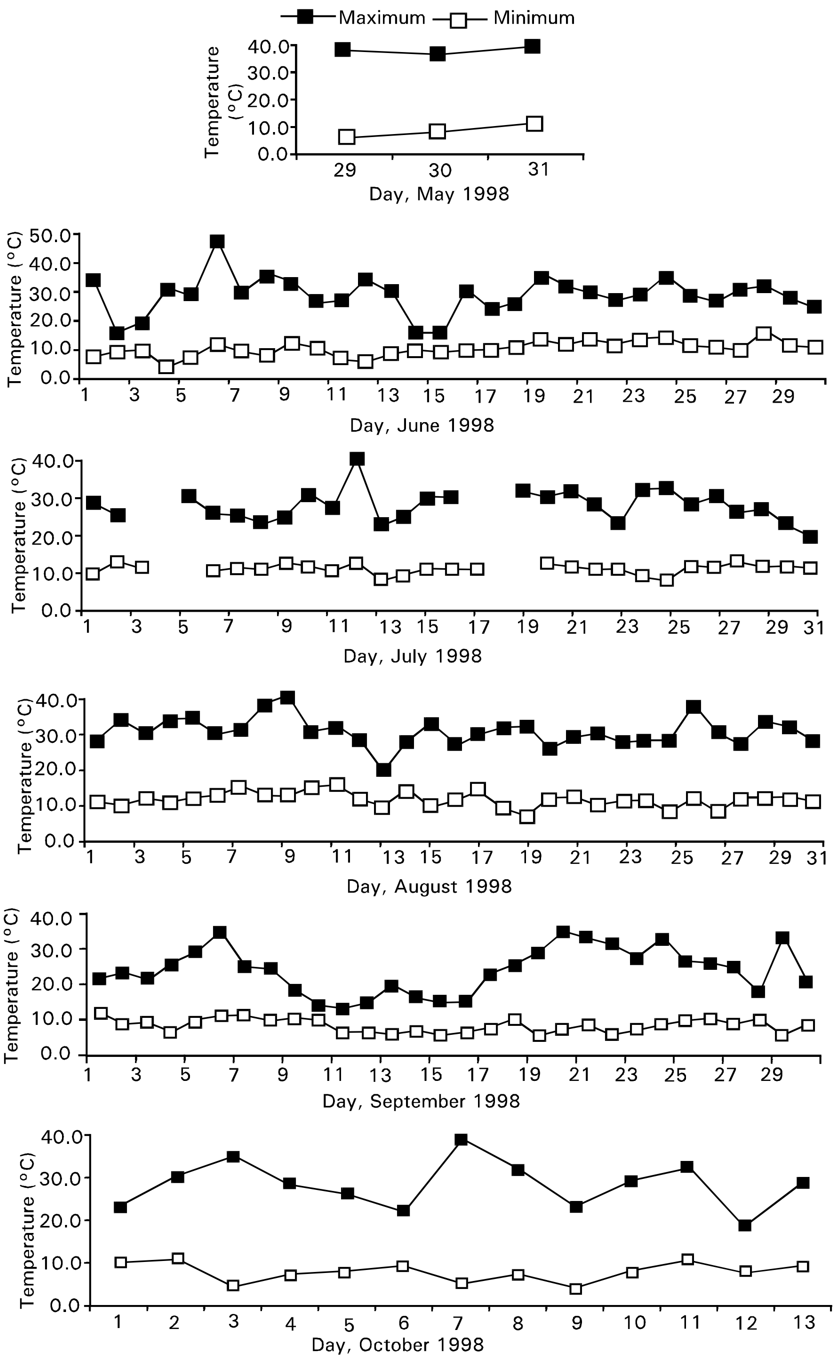

Fig. 1: Showing the glasshouse temperatures during the study (crops harvested on the 13th of October in 1998)

was reduced to two times per week, followed by once per week and finally was stopped. The maximum and the minimum glasshouse air temperatures were recorded daily (Fig. 1).

When the flowers bloomed they were tagged, with a label, noting the day of flowering. At maturity of the plant the date of maturity was also recorded. The pods from each plant were harvested separately according to their node position (node 1 = lower most) and date of flowering. Pods from main stem and branches were collected separately. After harvesting the pods were kept separately in paper bags for air drying in the laboratory. The seeds from pods on the main stem were threshed and counted and their fresh weight recorded according to node position, from which 100 seed weight was calculated. For each individual plant the total yield from the main stem at all nodes was determined. Then, the percentage of the total yield at each node was also calculated as:

$$\text{Average yield at node "n"} = \frac{\text{Total yield from all node "n"}}{\text{Number of plants with node "n"}}$$

$$\text{\% of yield at node "n"} = \frac{\text{Average yield at node "n"}}{\text{Average total yield from all nodes}} \times 100$$

Seeds were then stored to allow for dormancy breaking. Samples of seed were tested periodically for germination to assess whether or not dormancy had been broken. When their dormancy was broken germination was tested. The germination of seeds from different node positions on the main stem and branches were determined separately. Seeds were allowed to germinate in 9.5 cm diameter plastic petridishes with two layers of Whatman No. 1 filter paper and kept moist with distilled water. The petridishes were kept at 20°C in the dark in an incubator. Germination was recorded every day and a seed was considered germinated when its radicle protruded out about 2 mm. Germinated seeds were counted until no further germination occurred.

Statistical analysis: All the data were analyzed using Minitab Statistical Package, Version-12. Basic statistics was performed on the data for calculation of standard error of the means and a two sample-t-test was performed to compare the effects of spacings (40 and 20 cm) on seed yield and yield components. A regression analysis was also performed on the data to look at the relationship between node numbers and days from sowing to flowering, sowing to maturity and flowering to maturity. The individual pots were considered as replicates.

Results

The effects of node position on flowering, pod production, seed yield and germination percentage at 40 and 20 cm spacing are shown in Fig. 2 and Table 1. Note that the data for yield and yield components are for the main stem only. The relationship between node position and the duration of different development periods was investigated using regression analysis. In each case, at both 20 and 40 cm spacing there was a significant relationship ($P < 0.05$) between node position and days to different development stages. For the number of days from sowing to flowering the values of the slope (±SE) were 1.89±0.20 and 2.27±0.08, for the number of days from flowering to maturity the values of the slope (±SE) were –0.25±0.09 and – 0.88±0.17 and for the number of days from sowing to maturity the values of the slope (±SE) were

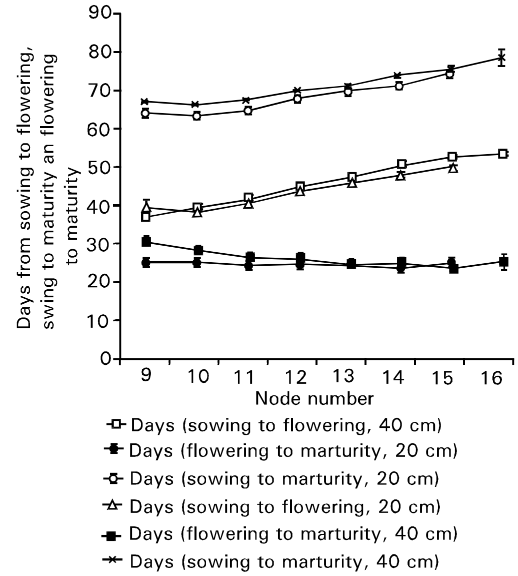

Fig. 2: Effects of node position on the mother plant on days from sowing to flowering, sowing to maturity and flowering to maturity at 40 and 20 cm spacings of peas cv. Baccara (vertical bars are ± SE of the means)

1.64±0.23 and 1.54±0.19 at 20 and 40 cm spacing respectively. In each case the values of the slope were significantly different from zero ($P < 0.05$).

The results (Table 1) shows that at 40 cm spacing most flowers and pods were borne on nodes 11, 12, 13 and 14. Nodes 10 and 15 had fewer flowers and pods and nodes 9 and 16 had very few flowers and pods. Days to flowering and days to maturity (Fig. 2) both increased with node position up the plant. However the number of days from flowering to maturity decreased only slightly, from 28 days at node 10 to 24 days at node 16 (Fig. 2). Number of pods per node, number of seeds per pod, seed weight and 100 seed weight were highest at node positions 10, 11 and 12 and decreased with node position from node 13 to node 16. All seeds at all nodes germinated (Table 1).

At 20 cm spacing most flowers and seeds were borne on nodes 10, 11, 12 and 13. Node 9 had fewer flowers and seeds and node 15 had very few flowers and seeds (Table 1). Days to flowering and days to maturity both increased with node position on the plant. However the number of days from flowering to maturity decreased slightly from 25 days at node 9 to 23 days at node 14 (Fig. 2). Number of pods per node, number of seeds per pod, seed weight and 100 seed weight were highest at node positions 10 and 11 and decreased with node position from node 12 to 15 (Table 1). Table 1 also shows

Table 1: Effects of spacing at 40 and 20 cm on flowering, pod production, yield and germination of peas from different nodes (1= lowest) on the main stem and germination on the main stem and branches. Data are means (± S.E) of 24 plants

Node numbers	9	10	11	12	13	14	15	16
% plants with flowers at each node								
40 cm spacing	4	58	88	92	100	100	92	38
20 cm spacing	29	92	100	100	100	83	21	....
% plants with seeds at each node								
40 cm spacing	4	58	88	92	100	92	71	21
20 cm spacing	29	88	96	96	88	42	4	....
Number of pods per node								
40 cm spacing	2.0±0.00	1.9±0.07	1.9±0.06	1.9±0.04	1.7±0.08	1.7±0.09	1.5±0.12	1.6±0.24
20 cm spacing	1.8±0.14	1.7±0.10	1.9±0.06	1.6±0.10	1.3±0.10	1.0±0.00	1.0±0.00	....
Number of seeds per nodes								
40 cm spacing	6.0±0.00	9.7±0.70	10.0±0.47	9.9±0.57	8.9±0.59	7.5±0.54	4.5±0.77	4.6±0.51
20 cm spacing	8.7±1.06	9.6±0.64	10.0±0.52	7.2±0.72	4.4±0.60	3.6±0.42	2.0±0.00	....
Number of seeds per pod								
40 cm spacing	3.0±0.00	5.1±0.36	5.3±0.27	5.0±0.25	4.9±0.22	4.5±0.27	2.9±0.42	3.0±0.27
20 cm spacing	4.7±0.43	5.5±0.16	5.3±0.24	4.5±0.40	3.7±0.43	3.6±0.42	2.0±0.00	....
Total seed weight (g)								
40 cm spacing	2.17±0.00	3.32±0.23	3.42±0.15	3.43±0.18	3.01±0.20	2.51±0.18	1.43±0.29	1.47±0.23
20 cm spacing	2.77±0.38	3.11±0.20	3.29±0.19	2.29±0.24	1.31±0.18	1.09±0.15	0.53±0.00	....
100 seed weight (g)								
40 cm spacing	36.18±0.00	33.98±0.65	34.55±0.94	35.07±0.70	33.84±0.69	33.5±0.86	28.39±2.32	31.29±3.41
20 cm spacing	30.86±1.13	32.42±0.76	32.28±0.77	30.63±0.91	28.62±0.86	29.95±1.17	26.99±0.00	....
% of total yield per node								
40 cm	13.43±0.00	22.55±1.80	23.34±1.28	23.02±1.49	20.50±1.82	16.94±1.63	9.46±1.74	9.00±1.61
20 cm	31.16±1.76	32.33±2.30	32.66±2.47	21.52± 2.19	12.72±1.85	10.73±1.86	4.71±0.00	....
Germination % (main stem)								
40 cm	100.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00
20 cm	100.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	....
Germination % (branches)								
Node numbers	5	6	7	8	9	10	....	....
40 cm	100.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	98.08±1.92	93.57±4.42	....	....
20 cm	100.00±0.00	100.00±0.00	100.00±0.00	95.83±4.17	95.24±4.76	90.46±0.46	....	....

Table 2: Effects of spacing at 40 and 20 cm on yield and yield components of peas

	Spacings (cm)		
	40	20	P-value
Number of branches/plant	0.54±0.12	0.25±0.11	NS
Number of pods/plant	11.13±0.37	7.88±0.36	< 0.001
Number of seeds/plant	49.17±1.68	34.46±1.07	< 0.001
Number of seeds/pod	4.45±0.11	4.52±0.18	NS
100 seed weight	33.73±0.49	33.71±1.09	NS
Seed yield on main stem (g/plant)	16.49±0.48	11.54±0.41	< 0.001

the mean percentage of the total yield on main stem per plant at each node. At 40 cm spacing nodes 10, 11, 12 and 13 produced most of the yield and at 20 cm spacing nodes 9, 10, 11 and 12 produced most of the yield.

The germination percentage of seeds from the main stem was constant at every node position for both spacings as all seeds germinated. Though there were no differences in germination percentage of the seeds produced from the main stem, but the seeds produced from the upper node of the branches showed a variation in germination percentage. At 40 cm spacing seeds from branches showed higher germination percentage than seeds produced from the branches at 20 cm spacing.

Effects of node position and spacing at 20 and 40 cm on plant growth and development: At 40 cm spacing a much higher proportion of plants produced flowers, pods and seeds than at 20 cm spacing. At 20 cm spacing the number of flowers, pods and seeds were greater in lower nodes (9, 10) and lower in upper nodes (14, 15) than at 40 cm spacing. At 20 cm spacing there were no flowers, pods or seeds at node 16. The number of days to flowering and days to maturity were both slightly lower at 20 cm spacing than at 40 cm spacing plants. The differences in number of days to flowering at each node between the spacings were small. Number of pods per node, seeds per node and pod, seed weight and 100 seed weight were generally lower at 20 cm spacing than at 40 cm spacing at all nodes.

Effects of node position and spacing at 20 and 40 cm on seed yield: The differences in seed weight and 100 seed weight between the two spacings were relatively small at nodes 10 and 11 but were much larger at nodes 12 to 16. At 40 cm spacing the highest percentage of yield was produced from node 11 (23.34%) and the lowest percentage of yield was produced from the node 16 (9.00%), at 20 cm spacing the highest percentage of yield was produced from node 11 (32.66%) and the lowest percentage of yield was produced from the node 15 (4.71%).

Effects of node position and spacing at 20 and 40 cm on seed germination: There were no differences in germination percentage of the seeds produced from the main stem but the seeds produced from the branches showed a variation in germination. The germination was similar in the lower nodes but they showed a wider variation in the upper nodes on the branches.

In general, at the closer spacing, more of the flowers, pods, seeds and yield was found on the lower nodes of the plant. Closer spacing did not affect the germination percentage of seed on the main stem, but resulted in a small decrease in germination percentage of seeds on the upper nodes of the branches.

Results showed the effects of spacings at 40 and 20 cm on seed yield and yield components (Table 2). Seed yield per plant on the main stem, number of pods per plant and number of seeds per plant were all significantly higher at 40 cm spacing than at 20 cm spacing. There was no effect of spacing upon 100 seed weight, number of branches per plant and number of seeds per pod.

Discussion

It is well known that large differences in viability and vigour occur between commercial batches of seeds. These differences might be due to the environment in which the parent plants are grown. A further factor affecting the characteristics of seeds within any batch is the source of the seeds within the seed crop. Another source of variability in seed quality may be associated with seed position on the mother plant (Cavers and Harper, 1966; Baranauskiene, 1977; Gray and Steckel, 1983). Several studies with seeds of carrot have indicated that seed size plays an important role in germination performance and the largest seeds are usually found on primary umbels with better germination performance. Seed size declines with order of umbel (Borthwick, 1931; Austin and Longden, 1965; Hunter, 1971; Shevtsova and Khleborodov, 1976; Gray and Steckel, 1980). The position of the seed on the parent plant has been suggested as a cause of variability in seed quality within individual seed lots (Malik and Kanwar, 1969; Ries *et al*., 1976; Thomas *et al*., 1979; Gray and Steckel, 1980).

The results of the present studies shows that in peas 100 seeds weight generally decreased with increasing node position. The germination percentage of peas was similar at all nodes on the main stem but seeds produced from the branches showed a small decrease in germination in upper nodes. Normally changing the spacing alters competition above and below ground but in this study, plants were grown in individual pots and maintained at 20 and 40 cm spacing between plants. So in this experiment spacing altered the competition above ground only. Although spacing altered competition above ground only, yet the spacings 40 and 20 cm between plants showed a clear marked difference of seed yield. Seed weight (per node position and total seed weight) were higher at 40 cm spacing than at 20 cm spacing. This higher seed weight per plant at 40 cm spacing was associated with higher number of branches per plant, number of pods per plant and number of seeds per plant. As 40 cm spacing experienced less competition than 20 cm spacing, this might be the cause of showing better performance in producing yield and yield components.

In peas at both spacings number of days to flowering increased with node position on the plant but number of days from flowering to maturity generally decreased with node position on the plant. This decrease might be associated with decreasing seed size with node position on the plant. At 20 cm spacing greater proportion of total yield was found at lower nodes on main stem but at 40 cm spacing higher proportion of yield was found from central to upper nodes.

It was observed that at closer spacing, more of the flowers, pods, seeds and yield was found on the lower nodes of the plant. But node position had little effect on germination, except that at both spacings there was a small decrease in germination of seeds on the upper nodes of the branches (Table 1). The reason of having higher yields at closer spacing on the lower nodes and low germination on the upper nodes of the plant might be due to more intra-plant competition than at higher spacing. Due to competition the seeds at the upper nodes of peas might have less chance to develop properly because competition appear earlier in stands of high density and progressively later in stands of lower densities (Donald, 1958, 1963; Harper, 1961).

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