Table 2. *Global fruit set of the different cultivars.*

Cultivar	1991			1992			1993		
	No. flowers	Set (%)	Yield rating	No. flowers	Set (%)	Yield rating	No. flowers	Set (%)	Yield rating
Cristomorto	12,109	4.31 a ^z	0.1 ^y	3,093	16.10 b	3.0	3,820	20.58 b	3.7
Ferraduel	10,252	5.87 b	0.1	9,432	8.68 a	1.5	6,895	13.88 a	3.2
Ferragnés	15,623	4.63 a	0.1	15,667	8.67 a	1.3	10,401	15.11 a	3.0

^zSets for each year followed by different letter are different by LSD test at $P \leq 0.001$.

^yYield rated on a 0 to 5 scale; 5 could represent 2000 kernel yield/ha.

Table 3. *Analysis of fruit set as related to the proximity to a pollinizer.*

Cultivar	Rows	Set (%)		
		1991	1992	1993
Ferraduel	1-3	6.22 a ^z	8.74 a	15.05 a
Ferraduel	2	4.99 b	8.56 a	11.60 b
Ferragnés	1-6	5.93 a	11.03 a	17.08 a
Ferragnés	2-5	4.05 b	7.82 b	14.42 b
Ferragnés	3-4	3.92 b	7.34 b	14.09 b

^zSets for the same cultivar and year followed by different letter are different by LSD test at $P \leq 0.01$.

the same behavior during the 3 years, with sets of rows 1 and 6 being significantly higher than those of the other rows, which did not differ between them. The lack of differences between the sets of rows 2 and 5 vs. 3 and 4 may be due to the absence of a pollinizer row close to any of these rows. Hill (1989) showed that bees fly from one cultivar to another up to 24% of times when the pollinizers are distributed in alternate rows, but the change of cultivar is reduced to 15% if the orchard design is that of 1 row-2 rows of different cultivars. There is a further decrease in bee efficiency if the rows of pollinizers are placed further apart. Hill (1989) described as ideal the orchard design of alternate trees on alternate rows, where bees change cultivar as often of 32% of the time, but this design would not be convenient for orchard management.

Pollen transfer from one cultivar to the other is quite reduced, even with the presence of bees, taking place mostly between tree halves of contiguous rows, without progression through the rest of the orchard (Jackson and Clarke, 1991). This explains the higher sets of 'Cristomorto' as compared to the other cultivars, even with the best sets of 'Ferraduel' and 'Ferragnés' (Tables 2 and 3), because 'Cristomorto' has pollinizers on both sides. Other cultivars have only a pollinizer on one side in the best situation.

These results show that this orchard design is not advisable for efficient cross-pollination and production.

The higher presence of bees in 1993 has shown its positive effect for increasing sets, although they remain low, even for 'Cristomorto'. Sets were especially low at site B because beehives were not distributed evenly, showing that a good orchard design and proper bee management are essential for obtaining a crop in self-incompatible almond cultivars.

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Planting-date Effects on Early maturing Pigeonpea in a Short-season Environment

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Additional index words. *Cajanus cajan*

Summary. Determinate, photoperiod-insensitive genotypes of pigeonpea [*Cajanus cajan* (L.) Millsp.] have production potential for the short growing seasons of the temperate region. A 3-year field study was conducted to determine the effect of three planting dates on the growth and development of pigeonpea in Missouri. Seeds of four genotypes, ICPL 87 Isolation (85k), ICPL 85010, ICPL 85024, and ICPL 8304 were planted 1 May (PD1), 15 May (PD2), and 1 June (PD3). Germination of the earliest-planted seeds was <32%, but increased to an average of 57% for PD3. Earliest-planted seeds generally took the longest time to first flowering and harvest. The initial fresh pod harvest of plants from PD1 and PD2 overlapped. The earliest harvest was produced by ICPL 85024 from PD2 at 91 days (1300 degree-days C) after planting. Over the 3 years, the genotypes in PD1 produced the highest fresh pod weights (205-357 g/plant) and longest pods. Those of PD3 produced the lowest pod weight. The seed number per pod (three to four) and weight of 100 seeds (16-22 g) were generally unaffected by planting dates.

Pigeonpea is a leguminous crop adaptable to tropical and subtropical climates (Saxena, 1981;

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Sharma et al., 1981). It is a deep-rooted drought-tolerant crop (Sharma et al., 1981), and is used extensively in intercropping systems (Saxena, 1981). The seeds, with protein content of 19% to 28% (Morton, 1976), are a significant food legume for people in several countries. At present, there is a thriving specialty market in the United States for both the fresh and dry seeds. Pigeonpeas currently are imported, but there is the potential for satisfying this demand through local production. Most pigeonpeas are short-day plants, and the time to flowering can vary from 50 to 400 days (Summerfield and Roberts, 1985). Based on the period required for pod maturity, pigeonpea can be divided into four groups—extra early (<100 days), early (up to 150 days), medium (160–180 days), and late (>200 days) (Gupta et al., 1987). Early maturing types having photoperiod-insensitivity have been identified (Meekin et al., 1987). These have the potential to develop and yield marketable pods during the relatively short growing seasons typical of temperate environments. The best planting time for optimum growth and yield of pigeonpea is unknown under these conditions. This study was conducted to determine the effects of different planting dates on the development and productivity of selected early maturing pigeonpeas grown in the short growing season conditions of a temperate region.

Materials and methods

Seeds of pigeonpea genotypes ICPL 146, 1985 HK, and ICPL 87 [from B. Cooper, Caribbean Agriculture Research and Development Institute (CARDI), Antigua, West Indies] and ICPL 85010, ICPL 85024, and ICPL 8304 (from D. Davis, Univ. of Minnesota, St. Paul), were planted at Lincoln University's Carver Farm (soil type Aquic Hapludalfs, fine-silty, mixed, mesic, pH 5.5) on 1 May (PD 1), 15 May (PD 2), and 1 June (PD 3) of 1990, 1991, and 1992. Early in each year, soil was prepared conventionally and trifluralin was incorporated to control weeds. Seeds (two each) were hand-planted at a depth of 4 cm and 0.3 m apart in three-row plots 4.5-m long with 0.9 m between rows. The design was a split-plot in a randomized complete block, with genotypes as main plots and planting dates as subplots, with three replications. Rainfall was monitored by a Weathertronic rain gage

(Weathertronic, Sacramento, Calif.). Soil temperature at 8-cm depth and air temperatures were recorded by Weathertronic remote three-point thermographs (Qualimetric, Sacramento, Calif.) and Cole Parmer hygrothermographs (Cole Parmer, Chicago), respectively. Degree-day (C) was determined as the sum per day of the average of the maximum and minimum air temperature minus the base temperature of 10C. Plants were irrigated weekly by sprinkler irrigation (≈ 15 mm per application) when needed. For the first 2 years of the study, pod borers were controlled by spraying weekly with malathion or diazinon at a rate of 3 ml·liter⁻¹. In the final year, Dipel (*Bacillus thuringiensis* var. *kurstaki*) at a rate of 3 ml·liter⁻¹ was used because the malathion was ineffective.

Percent seedling emergence at 21 days after planting was determined. At 35 days after planting, the plots were thinned to one plant per 0.3 m where possible. The number of days from planting to the beginning of flowering was recorded when the first flowers

were observed in the center row. At this time, plant heights of three plants in the center row were measured. Other data were recorded from three plants in the center row: the number of days from planting to fresh harvest, weight of freshly harvested pods, pod length, and weight of 100-seed samples. Fresh harvest was determined at the stage when the pods were firm with firm, moist seeds of 63–70% moisture. Reported data are a composite of five to seven harvests.

Results and discussion

The analyses of variance for each of the variables combined over the 3 years showed significant interactions of planting date $\times$ year and genotype $\times$ year. Due to these interactions, the analyses were instead done separately for each year for each of the variables.

Percent emergence. Pigeonpeas planted earliest (1 May) had <32% emergence in 1990 and 1991 (Table 1). Seedling emergence from this planting was generally the lowest for seeds in the three planting dates, and was

Table 1. *Planting date effects on percent emergence of pigeonpea at 21 days after planting over 3 years*

Genotypes (G)	Planting dates (P)								
	1990			1991			1992		
	1 May	15 May	1 June	1 May	15 May	1 June	1 May	15 May	1 June
	Percent								
ICPL 87	2	4	52	32	67	63	52	63	52
ICPL 85010	10	40	40	17	47	47	42	53	54
ICPL 85024	12	27	98	13	37	47	38	43	61
ICPL 8304	2	29	50	15	47	54	57	60	51
G	NS			**			**		
P	**			**			NS		
G $\times$ P	NS			NS			NS		
LSD ² , 0.05	41			13			18		

²LSD values for the means in rows and columns for each year.

NS,**Nonsignificant or significant at $P \leq 0.01$, respectively.

Table 2. *Planting date effects on plant height at flowering for pigeonpea genotypes grown in Missouri over 3 years*

Genotypes (G)	Planting dates (P)								
	1990			1991			1992		
	1 May	15 May	1 June	1 May	15 May	1 June	1 May	15 May	1 June
	centimeters								
ICPL 87	92.0	96.6	88.3	78.3	81.0	81.0	57.3	62.7	93.1
ICPL 85010	79.0	93.7	75.3	73.0	69.7	84.7	47.7	66.2	85.5
ICPL 85024	66.9	71.6	67.3	65.0	59.0	76.0	54.3	59.3	86.7
ICPL 8304	88.9	85.7	73.7	66.7	81.3	84.3	46.7	72.1	87.4
G	**			**			**		
P	NS			**			**		
G $\times$ P	NS			NS			NS		
LSD ² , 0.05	13.2			12.4			18.5		

²LSD values for the means in rows and columns for each year.

NS,**Nonsignificant or significant at $P \leq 0.01$, respectively.

most likely due to low temperatures (sometimes averaging <10C at night) during the first 3 weeks after planting at these times. Similar results at low temperatures have been reported by de Jabrun et al. (1981), who observed that radicle emergence of pigeonpea in standard germination tests declined abruptly below 19C. During 1990 and 1991, emergence generally increased as planting date was delayed and soil temperatures increased. In contrast, percent emergence of all genotypes except ICPL 85024 was unaffected by planting date in 1992. Two of the genotypes, ICPL 87 and ICPL 8304, attained their maximum emergence in the earliest planting. This lack of response to planting date was due to a combination of moderate rainfall (40 mm) and atypically high minimum temperatures at the first planting, while an extended period of lower minimum temperatures (<10C) for 1 week was experienced at the second planting. The overall emergence over the 3 years was low (43% and 57%) at these later dates, and may be due to

soil crusting after rainfall, which impeded the elongation of the plumule, or washing out of seeds by heavy rains. Standard rolled towel tests of the seeds had showed 85% germination before field planting was done.

Plant height. Consistent with the report of Brakke and Gardner (1987), the plants grew slowly during the first 50 days. At first, flowering plant height generally was unaffected by planting date in 1990, but was greater for those in PD3 than those in the earlier plantings in 1991 and 1992 (Table 2). Like most of the other variables measured, the genotypes $\times$ planting date interaction was not significant.

Days to first flower. The earliest-planted pigeonpea genotypes generally took a longer time to flower than the two later-planted types, except in 1992 (Table 3). In this year, most plants in PD1 took the same number of days to begin flowering for PD2 and PD3, due to the atypically high temperatures received at PD1. Except for ICPL 85024 and ICPL 87, the geno-

types of PD2 and PD3 did not differ in number of days to first flowering in 1992. The similarity in the results for the two dates in 1990 and 1991 is due to the higher temperatures of the two later planting dates, which promoted the thermoperiod effect experienced by pigeonpeas (Mohamed and Ariyanayagam, 1993). On the other hand, the lower temperatures at PD1 during these two, delayed plant development. Although the earliest-planted pigeonpeas took a longer time to first flowering, they were still the earliest-maturing when actual time is considered. Over the 3 years, they flowered 4 to 11 days earlier than those of PD2, which, in turn, flowered 14 to 16 days earlier than those of PD3.

Days to harvest. In 1991, delay in planting dates caused a steady decrease in days to harvest for ICPLS 85010 and 8304, but an increase from PD2 to PD3 for the other two genotypes (Table 4). In 1990 and 1991, all genotypes of PD1 took a longer time to mature than those of PD2 and PD3, which were comparable. However, in 1992, plants from the three planting dates did not differ in length of the time to first harvest, except for ICPL87 and ICPL8304. Again, based on the temperature conditions at planting, this response is expected and shows a pattern similar to that of the emergence and days to flower in this year (Tables 1 and 3). When the actual time at first fresh harvest is considered, the PD1 and PD2 pigeonpeas in 1990 and 1991 reached this stage within 4 days of each other. However, PD1 pigeonpeas matured 9 to 15 days earlier than the PD2 crop planted in 1992. Over the 3 years, plants from PD3 matured 626 days later than those in the second planting. The earliest harvest was produced on 14 Aug. 1991 by ICPL 85024 from PD2 at 91 days (1300 degree-days C).

Pod and seed characteristics. Earliest-planted pigeonpea generally produced greater pod weight than the latest-planted crops from PD3 in 1990 and 1991 (Table 5). Except for ICPLs 8304 and 87 in 1990 and ICPL 85010 in 1991, these weights were not different from those of PD2. The lower weights are due to the later and fewer harvests from PD3 pigeonpeas. An average of five harvests were completed from PD3 plants, while seven and six harvests were obtained from PD1 and PD2 plants, respectively. In 1992, planting dates did not affect fresh pod weight.

Table 3. *Planting date effects on days to first flower for pigeonpea genotypes grown in Missouri over 3 years*

Genotypes (G)	Planting dates (P)								
	1990			1991			1992		
	1 May	15 May	1 June	1 May	15 May	1 June	1 May	15 May	1 June
	<i>Days</i>								
ICPL 87	100	99	83	81	70	71	68	63	70
ICPL 85010	98	87	80	76	62	65	68	64	67
ICPL 85024	78	84	68	67	55	63	69	62	70
ICPL 8304	94	82	73	80	61	64	68	63	65
G	**			**			NS		
P	**			**			**		
G $\times$ P	NS			NS			NS		
LSD ² , 0.05	11			7			5		

²LSD values for the means in rows and columns for each year.

NS, ** Nonsignificant or significant at $P \leq 0.01$, respectively.

Table 4. *Planting date effects on days to harvest for pigeonpea genotypes grown in Missouri over 3 years*

Genotypes (G)	Planting dates (P)								
	1990			1991			1992		
	1 May	15 May	1 June	1 May	15 May	1 June	1 May	15 May	1 June
	<i>Days</i>								
ICPL 87	142	125	117	127	109	116	130	113	123
ICPL 85010	132	115	118	117	107	99	114	116	125
ICPL 85024	129	114	110	108	91	99	114	113	125
ICPL 8304	129	115	115	119	105	99	114	109	127
G	**			**			NS		
P	**			**			**		
G $\times$ P	NS			S**			NS		
LSD ² , 0.05	7			5			12		

²LSD values for the means in rows and columns for each year.

NS, ** Nonsignificant or significant at $P \leq 0.01$, respectively.

Table 5. *Planting date effects on on fresh pod weight/plant of pigeonpea genotypes grown in Missouri over 3 years.*

Genotypes (G)	Planting dates (P)								
	1990			1991			1992		
	1 May	15 May	1 June	1 May	15 May	1 June	1 May	15 May	1 June
	<i>Grams</i>								
ICPL 87	730	479	289	302	319	176	144	65	80
ICPL 85010	477	407	296	326	170	200	38	106	144
ICPL 85024	333	198	127	167	97	150	118	104	104
ICPL 8304	702	355	164	356	276	175	147	135	164
G	*			**			*		
P	**			**			NS		
G × P	NS			*			*		
LSD ^z , 0.05	328			82			69		

^zLSD values for the means in rows and columns for each year.

NS, *, ** Nonsignificant or significant at P ≤ 0.05 or 0.01, respectively.

Table 6. *Planting date effects on pod length of pigeonpea genotypes grown in Missouri over 3 years.*

Genotypes (G)	Planting dates (P)								
	1990			1991			1992		
	1 May	15 May	1 June	1 May	15 May	1 June	1 May	15 May	1 June
	<i>Centimeters</i>								
ICPL 87	5.4	5.4	5.6	6.0	6.1	5.9	5.6	4.4	4.4
ICPL 85010	5.4	5.7	5.3	5.7	5.4	5.8	5.5	4.4	4.5
ICPL 85024	5.1	4.9	4.9	5.4	5.1	5.2	4.9	4.3	4.2
ICPL 8304	5.7	5.1	5.5	5.7	5.2	5.3	4.8	4.0	4.0
G	*			**			*		
P	NS			NS			**		
G × P	NS			NS			NS		
LSD ^z , 0.05	0.6			0.6			0.8		

^zLSD values for the means in rows and columns for each year.

NS, *, ** Nonsignificant or significant at P ≤ 0.05 or 0.01, respectively.

Table 7. *Planting date effects on 100-seed weight pigeonpea genotypes grown in Missouri over 3 years.*

Genotypes (G)	Planting dates (P)								
	1990			1991			1992		
	1 May	15 May	1 June	1 May	15 May	1 June	1 May	15 May	1 June
	<i>Grams</i>								
ICPL 87	20.4	20.5	20.0	21.6	20.0	21.0	18.3	17.0	17.0
ICPL 85010	20.5	18.9	18.5	20.7	19.3	19.6	23.0	19.3	20.7
ICPL 85024	17.3	16.9	15.8	17.7	15.5	19.4	15.3	14.3	15.3
ICPL 8304	19.2	16.7	19.2	19.6	17.9	18.9	16.5	17.3	16.3
G	**			**			**		
P	NS			**			NS		
G × P	NS			NS			NS		
LSD ^z , 0.05	2.7			1.7			4.7		

^zLSD values for the means in rows and columns for each year.

NS, *, ** Nonsignificant or significant at P ≤ 0.01, respectively.

Pod lengths of pigeonpeas from PD1 in 1992 were generally greater than those of the later plantings, but were unaffected by planting date in the previous 2 years (Table 6). The average number of seeds per pod (three to four) was unaffected by planting date. Two genotypes (ICPL 87 and ICPL 85010) generally had greater 100-seed weight (17.0–23.0 g) than the other two genotypes (Table 7). One geno-

type, ICPL 85024, had lower 100-seed weights for the PD2 plants in 1991. In the other 2 years, planting date did not affect seed weight.

Of the three planting dates, PD1 (1 May) and PD2 (15 May) are more suitable for planting pigeonpeas in mid-Missouri and still produce marketable yield in the season. This is due to the earlier harvest and greater seed yields of PD1 and PD2 plants. Planting at

PD2 provides average soil and air temperature of 20C and 19C, respectively, which are favorable for seedling emergence and early growth. However, the overall emergence and stand establishment needs to be increased by correcting such problems as soil crusting. Pigeonpeas from PD1 provided higher or similar yields to the plants from PD2 by compensating for the poor stands that come from very low seedling emergence (25%). Seedling emergence is best (57%) for PD3, but the yield in mid-Missouri is lowest due to late maturity.

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