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Planting Cauliflower to a Stand with Precision Seeding

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Abstract. **Field studies were conducted in Fall 1991 and 1992 to determine 1) if cauliflower *(Brassica oleracea* L. Botrytis Group) could be precision-seeded to a stand without subsequent thinning and 2) the optimum seed spacing necessary to directly seed cauliflower to a stand. Seed spacings of 10, 20, and 30 cm at one seed per hill and 30 cm at two seeds per hill were evaluated for effect on yield, head weight, plant population, and early harvest percentage. As evaluated in the laboratory, seeder precision (accuracy) was good in regard to seed counts and spacing measurements at the various seed spacings. In the field, seeder precision varied in distribution patterns among seed spacings and years. Cauliflower directly seeded at one seed per hill and a 20-cm spacing produced yields and head weights similar to cauliflower seeded 10 cm apart and thinned to 30 cm—the seeding method currently used by some commercial operators.**

Establishing a full stand of field-grown plants is necessary to efficiently produce high cauliflower yields. To ensure that an adequate stand will be obtained, producers generally direct-seed cauliflower at a higher plant population than desired. Two to 3 weeks after planting, the stand is thinned manually to the recommended within-row spacing (WRS) of 30 cm (Boudreaux, 1991). Because of the high cost of hybrid seed and the shortage and expense of manual labor, any reduction in seed or thinning requirements would be an economic advantage to cauliflower growers.

Research for improving stand establishment in *Brassica* spp. has focused on seeding for a post-thinned stand or using seed treatments to enhance germination. Earlier and more uniform seedling emergence has been reported for many vegetable crops with fluid drilling (Gray, 1984), seed priming (Sundstrom et al., 1987), and seed hydration (Pill, 1990). Commercial acceptance of these seed treatments, however, has been low due to the specialized equipment required, the sophistication of the techniques, and the variable responses obtained (Finch-Savage, 1987; Kahn and Motes, 1988, 1989; Perkins-Veazie et al., 1989). Perkins-Veazie et al. (1989) reported that desired post-thinned stands and yields could be achieved with directly seeded cabbage (*Brassica oleracea* L. Capitata Group) under ideal or stressful conditions by using seed covers. Kahn and Motes (1988, 1989) determined that dry-seeded cauliflower and broccoli (*Brassica oleracea* L. Italica Group) produced satisfactory post-thinned stand establishment and yield. Seeding broccoli at double the final spacing is an effective, low-cost grower method for stand improvement (O'Dell, 1990). Bracy et al. (1993) reported that cabbage directly seeded at one seed per hill and a 30-cm spacing produced yields and head weights similar to or higher than cabbage seeded 10 cm apart and thinned to 30 cm.

We found no literature to support the possibility of directly seeding cauliflower to a final stand using precision seeding methods. Salter and Fradgley (1969) suggested graded seed could be sown singly in situ by precision drill for the production of cauliflower transplants but only reported effects on curd initiation and maturation. Therefore, a study was initiated to determine if cauliflower could be seeded to a desired stand without subsequent thinning or reduced yield and head size.

Materials and Methods

The experiments were conducted at the Hammond Research Station, Hammond, La., on a Cahaba fine sandy loam soil (thermic Typic Hapludult) during Fall 1991 and 1992. Fields were prepared, planted, and cultivated in the same manner for both plantings using the precision system developed by Parish et al. (1992). The herbicide 2,6-dinitro-*N*,*N*-dipropyl-4-(trifluoromethyl) benzenamine (trifluralin) was applied preplant at 0.75 $kg\cdot ha^{-1}$ and shallowly incorporated. Subsequent cultivations for weed control were made 5 and 7 weeks after planting. Fertilizer (5–20–20) was drilled at (in $kg\cdot ha^{-1}$) 49N–65P–123K preplant based on Louisiana Cooperative Extension Service recommendations (Boudreaux, 1991) and soil analysis. Supplemental N (NH_4- NO_3) was applied at 45 $kg\cdot ha^{-1}$ between the double rows on top of the beds at 5, 7, and 9 weeks after planting.

'White Cloud' cauliflower (Asgrow Seed Co., Kalamazoo, Mich.) was seeded 6 mm deep on 19 Sept. 1991 and 1 Oct. 1992 with precision seeders (model S870; Stanhay Webb, Suffolk, England) in two rows spaced 0.3 m apart on 1 × 56-m beds. Desired WRSs were 8 to 10, 15 to 20, and 25 to 30 cm at one seed per hill and 25 to 30 cm at two seeds per hill; these spacings will be referred to as 10-thin, 20-one, 30-one, and 30-two, respectively. After stand establishment, plants seeded at 10-thin were thinned 30 cm apart to simulate the currently used, local, commercial practice. Excess seeding rates of 30-two and 20-one were included

Table 1. The effect of seed spacings and count on seed and plant counts[z] of 'White Cloud' cauliflower in Fall 1991 and 1992.

	No. seed (laboratory)			No. plants (field)			
	1991			1991		1992	
Seeding treatments[y]	Expected	Actual	Difference[x]	Actual	Difference[w]	Actual	Difference[w]
10-Thin	35	53	18	22[v]	–31	23[v]	–30
20-One	17	20	3	13	–7	25	5
30-One	11	15	4	14	–1	11	–4
30-Two	22	27	5	21	–6	14	–13
Contrast effects of seed spacings							
10-Thin vs. 20-one			**		**		**
10-Thin vs. 30-one			**		**		**
10-Thin vs. 30-two			**		**		**
30-One vs. 30-two			NS		*		**

[z]Seeds counted in laboratory from 3 m of greased board; plants counted 3 weeks after planting from 3 m of row.
[y]Within-row spacings with one seed per hill at 8 to 10 cm = 10-thin; 15 to 20 cm = 20-one; and 25 to 30 cm = 30-one and within-row spacings with two seeds per hill at 25 to 30 cm = 30-two.
[x]Difference in actual seed counts in the laboratory and seed counts expected for each seed spacing.
[w]Difference in actual plant counts in the field and the actual seed counts determined in laboratory.
[v]Counts made before thinning.
[NS, *, **]Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

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to evaluate the need for compensation for irregular germination and seedling losses.

Precision seeder accuracy at the various spacings was evaluated in the laboratory before establishing field trials in 1991. Although the same seeding units were used both years, measurements were repeated in the laboratory during 1992. In the laboratory, the seeder was operated over a 3-m greased board at the ground speed used in the field, and then the spacing between the dropped seeds was measured. Grease prevented seed bouncing and retained exact seed placement. Seeds were counted at this time to determine actual seeding rate for comparison with expected seeding rate.

Before any subsequent field operations during 1991 and 1992, plants were counted and distances were measured in the field when plants were 50 to 80 mm high [20 days after planting (DAP)]. Immediately after plants were counted and distances were measured, plants in the 10-thin plots were thinned to 30 cm apart, and the remaining plants were counted and distances measured. The thinning operation approximated the field practice of local commercial operations; the final WRSs were not absolute, averaging 30.4 and 27.8 cm in 1991 and 1992, respectively. Plant counts in the 10-thin plots after thinning averaged 10.5 and 12.3 plants per 3 m of row in 1991 and 1992, respectively.

Average air maxima/minima during stand establishment (planting date through counting date) were 28/21C in 1991 and 27/18C in 1992. In 1991 and 1992, plants received 25 and 5 mm, respectively, of rainfall and 83 and 87 mm, respectively, from supplemental overhead-sprinkler irrigation. Additional sprinkler irrigations were provided during the experiment to prevent drought stress.

Selective harvests were made by plot, so heads were individually harvested when optimum maturity was obtained, regardless of plant population. For the 1991 planting, harvests began 105 DAP on 2, 7, and 11 Jan. 1992. For the 1992 planting, harvests began 97 DAP on 5 and 8 Jan. 1993.

Seed spacing treatments were arranged in the field in a randomized block design with four replications. Two 6-m subplots per bed were designated for data collection in the field. Four replications of each seed spacing were used for collecting laboratory data. Data were subjected to analysis of variance using the SAS general linear models procedure (SAS Institute, 1987), with subsequent contrast comparison of seed spacing treatments with the 10-thin control. The distribution of spacing intervals was evaluated by comparing variances within and among spacing treatments.

Results and Discussion

Seed and plant counts. Seed counts in the laboratory were higher than expected for all of the seed spacings evaluated (Table 1). The difference between actual and expected seed numbers was noticeable with 10-thin. Placement of two or three seeds, instead of one, per drop occurred randomly at all seeding rates but

Table 2. Comparison of uniformity of 'White Cloud' cauliflower seed placement (laboratory) and plant spacing (field, 1991 and 1992) by seed spacings and count.

	Seed treatments[z]			
Location	10-Thin	20-One	30-One	30-Two
	Distance between seeds (cm)			
Laboratory	7.7 b[y]	16.8 b	25.2 c	19.7 b
	Distance between plants (cm)			
Field, 1991	16.0 a	30.0 a	37.5 b	30.4 a
Field, 1992	15.5 a	14.6 b	44.2 a	31.6 a
	Contrast effects over seed spacings			
Laboratory vs. field	**			
1991 vs. 1992	**			

[z]Within-row spacings with one seed per hill at 8 to 10 cm = 10-thin; 15 to 20 cm = 20-one; and 25 to 30 cm = 30-one and within-row spacings with two seeds per hill at 25 to 30 cm = 30-two.
[y]Mean separation within columns by least square means at $P \leq 0.01$.

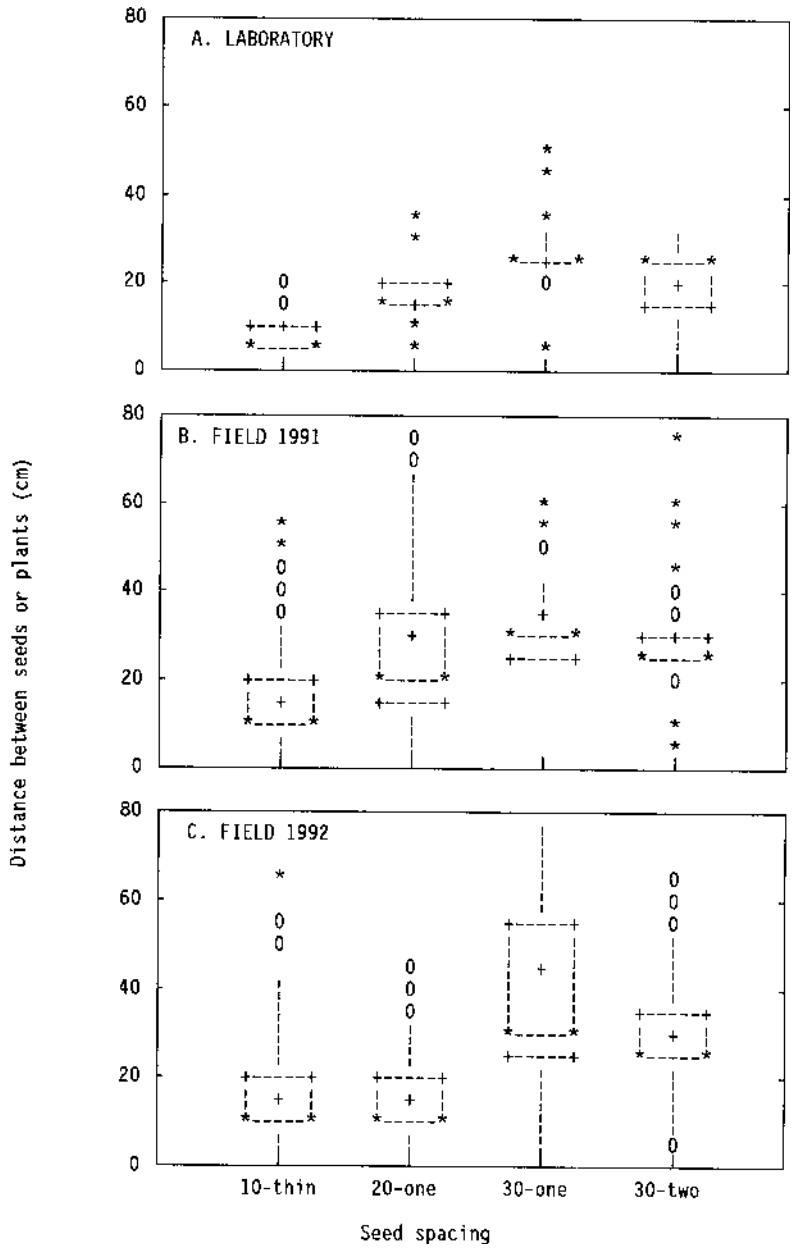

Fig. 1. (**A**) Effect of seed spacing on seed distribution in the laboratory and plants in the field during (**B**) 1991 and (**C**) 1992. The bottom and top edges of the box are located at the sample 25th and 75th percentiles, respectively (Tukey, 1977). The mean is indicated by the "+" and the median by the central dashed line ending with an "*" within each box. The central vertical lines extend from the box as far as the data extend to a distance of 1.5 interquartile ranges, with "0" and "*" indicating data within three interquartile ranges or more extreme.

was more frequent with 10-thin. Visual examinations of seeding belts did not indicate any mechanical reason for the excessive seeding for 10-thin, and belt hole size was correct for the cultivar being used. Laboratory seed counts taken in 1992 (data not shown) were similar to those recorded in 1991.

During both years, plant counts in the field for 10-thin plots were much lower than actual number of seed counted in the laboratory. Field plant counts for 10-thin plots were closer to expected seed counts than actual counts. The lower plant counts indicate that the multiple-seed drops in the laboratory were not repeated to the same extent in the field.

Contrast effects indicate that differences between expected and actual seed counts in the laboratory were significant between 10-thin and each of the other three seeding treatments. The difference in number of seed planted and plants present in the field for 10-thin was significantly less than the seed–plant differences for 20-one, 30-one, and 30-two seeding treatments. Difference in expected and actual seed number in the laboratory was not significant between 30-one and 30-two, but differences in number of seed planted and plants present in the field were significant between these two seeding rates.

Differences in number of seeds planted and number of plants present in the field were not significant between years ($P \leq 0.05$); however, seeding rate × year interactions were different. Seed counts made in the laboratory and evaluated over seed spacings were highly correlated with plant counts in the field during 1991 (r = 0.87) but not during 1992 (r = 0.50). Plant counts made in the field were not well correlated (r = 0.12) between years.

Seed and plant spacings. Spacing uniformity varied with seed spacing, location, and year (Table 2). Plant spacings in the field were wider than seed spacings in the laboratory at all spacings, except for 20-one in 1992, where spacings in the field and laboratory were similar. Seeds in this spacing were singulated, but many spacings were at 5 to 8 cm, indicating drag in the seed placement operation that was not evident in the laboratory.

Analysis of seed spacing, as measured in the laboratory, indicated little variance within any spacing (Fig. 1). Plant spacings in the field during 1991 and 1992 had wider ranges than seed spacings in the laboratory. We attributed the larger distances between plants to missing plants (preemergence losses and seedling diseases) and not to missing seed. Hegarty (1979) reported that preemergence losses of broccoli in the field were due in part to the inability of seedlings to emerge from the soil (soil impedance) and in part to biotic factors. Plant spacings during 1991 closely followed expected measurements. During 1992, the 30-one spacings were wider than expected, indicating that plant losses had affected final plant spacing.

Yield. Without adjusting fertilizer rates for higher plant populations, plants established at all seed spacings in 1991 produced similar counts (31,000 to 39,000) and weights (15.4 to 17.4 t·ha^{-1}) of marketable heads per hectare. Cauliflower heads that met the standards for U.S. no. 1 grade were considered marketable (Federal Register, 1981). During 1992, marketable weight was similar for plots seeded at 20-one and those seeded at 10-thin, with the same fertilizer rates for all WRSs (Table 3). Plants established at 30 cm with either one or two seeds per hill produced less marketable head weight per hectare than those grown at the 10-thin seed spacing.

Average head weights were similar for plants produced at all seed spacings in both years (402 to 455 g in 1991 and 253 to 285 g in 1992). Csizinszky and Schuster (1985) and Knavel and Herron (1981) reported larger individual cabbage heads from lower plant populations at a constant fertilizer rate for various WRS. Stoffella and Fleming (1990) found >60% of the experimental variation in cabbage head weight was associated with WRS. Percentage of total yield cut at the first harvest was not affected by spacing during either year (15% to 31% in 1991 and 39% to 61% in 1992). Although Halsey et al. (1966) found that decreasing the plant spacing increased the number of undeveloped cabbage heads, lack of uniformity within plant spacings during our experiments negated plant spacing effects (Fig. 1). The number of harvested heads for all seed spacings was similar during both years, although the average head weight in 1992 was ≈63% that in 1991.

Highest marketable head weight per hectare and highest average head weight were recorded on plots seeded to 30-one in 1991 and on plots seeded to 10-thin in 1992, but differences were significant only for marketable weight per hectare during 1992. Bracy et al. (1993) reported that cabbage directly seeded to one seed per hill and spaced 30 cm apart produced total and average head weights similar to or higher than cabbage seeded at 10 cm and thinned to 30 cm.

Results from these experiments indicate cauliflower was successfully precision-seeded to a stand without thinning. Cauliflower directly seeded at 20-one produced total and average head weights similar to cauliflower seeded at 10-thin during 2 years of fall plantings.

Table 3. Marketable heads of directly seeded 'White Cloud' cauliflower in response to seed spacings and count, 1992.

Seeding treatments[z]	Marketable heads Count (no./ha, 1000s)[y]	Wt (t·ha^{-1})
10-Thin	34.7	10.8
20-One	32.3	9.8
30-One	24.2	6.9
30-Two	26.6	7.6
Contrast effects of seed spacing		
10-Thin vs. 20-one	NS	NS
10-Thin vs. 30-one	NS	*
10-Thin vs. 30-two	NS	*
30-One vs. 30-two	NS	NS

[z]Within-row spacings with one seed per hill at 8 to 10 cm = 10-thin; 15 to 20 cm = 20-one; and 25 to 30 cm = 30-one and within-row spacings with two seeds per hill at 25 to 30 cm = 30-two.
[y]Based on number of heads (mean of four replications) harvested from 3 m of bed.
NS, *Nonsignificant or significant at $P \leq 0.05$.

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