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Effects of Container Size, Transplant Age, and Plant Spacing on Chinese Cabbage[1]

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Abstract. **Head weights of 'Nagaoka 55' Chinese cabbage (*Brassica rapa* L. ssp. *pekinenis* (Lour.) Olsson) were 76–79% greater at a plant spacing of 43 cm than at 28 cm. Percentage salable and grade 1 heads both increased with increasing distance between plants. Seedlings were raised in cylindrical containers of 2.5, 3.75, 5 and 7.5 cm diameter x 6.4 cm depth for 3, 4, 5 and 6 weeks in a seedling house. Transplant age affected maturity time minimally and did not affect yield. Seedling fresh weight was greater in 7.5 cm containers than in the smaller containers at all transplant ages. Plants started in 7.5 cm containers matured 7.5 days earlier, produced 10% heavier heads and yielded 25–31% more than plants started in 2.5 cm containers. Plants from the larger containers probably performed better as a result of the more favorable physical properties or fertilization regime of the container media. The highest yields in these trials exceeded 3 MT/ha · day.**

Chinese cabbage is the most important vegetable crop grown in China (6) and is the most popular oriental vegetable grown in the U.S. (11). Its culture lends itself to container transplanting and highly intensive production practices.

Container-grown transplants are being widely used in the vegetable industry for leafy crops such as lettuce and celery (2). Lettuce yield increases were obtained with increases in container size and transplant age (9). Larger head size and higher yields of cabbage were obtained by transplanting larger-sized seedlings when the container size and transplant ages were the same for all transplant sizes (7). The time period from transplanting to harvest was reduced by over 7 days when the transplant age of Chinese cabbage was increased from 24 to 33 days (10).

Wider plant spacings caused increased head size of lettuce (8), spear weight of broccoli (3) and main head and axillary head size of cabbage (1). When the plant spacing was irregular the head size of Chinese cabbage varied considerably (12).

The objectives of this study were to determine the effects of plant density on head size and quality of Chinese cabbage and the effects of transplant age and container size on head size, time to maturity and salable yields of Chinese cabbage.

Materials and Methods

Plant spacing studies were conducted with 'Nagaoka 55' Chinese cabbage in an unheated, open-ended plastic greenhouse at an elevation of 1200 m from late October to early February in 1975–76 and 1976–77. Transplant age and container size studies were conducted in a different greenhouse at the same site from March to May and June to September in 1980. Cultural practices, including fertilization were the same for all treatments. Potting media for all experiments consisted of a 2:3 ratio of a commercial vermiculite-peat mixture and greenhouse soil (Manu silt loam) supplemented with dolomite, 0-20-0 and 8-14-7 (N-P-K) at the rates of 3, 3.3 and 3.4 g/liter of media, respectively. Plants were watered by drip irrigation. The prevailing high humidity in the experimental area and frequent watering of newly transplanted seedlings ensured that seedling establishment was not hindered by plant or soil moisture stress (4). Mean daily low and high temperatures ranged from 11° ± 2°C to 26° ± 4°, respectively. Heads were classified as unsalable when they were loose or diseased whereas salable heads were firm or solid; solids heads were classified as grade 1.

Plant spacing. Five-week-old seedlings were transplanted on square spacings at distances of 28, 33, 38 and 43 cm in Experiment I, with an additional spacing of 48 cm included in Experiment II. Seedlings were raised in tapered square containers with a 5 cm top × 5 cm depth and a volume of 100 cc. Depending upon the plant spacing, 10–20 plants were individually harvested from the center 2 rows of 4-row plots when they matured. The experiments were arranged as randomized complete blocks with a minimum of 3 replications.

Container size and transplant age. A transplant container size (2.5, 3.75, 5, and 7.5 cm diameter × 6.4 cm depth) × transplant age experiment (3, 4, 5, 6 weeks) was arranged in a 4 × 4 factorial design with 4 replications. The containers consisted of cylindrical polyethylene sleeves. Transplanting was performed on the same day for all treatments and the plant spacing was 46 × 36 cm. The entire plot of 10 heads was harvested at one time when a majority of the heads were determined to be mature. Data collected included seedling fresh weight at transplanting time, salable yield, head weight and age at harvest.

Results and Discussion

Plant spacing. Head weight increased with decreasing plant density (Table 1). Head weights were 76–79% greater at 43 cm spacing than at 28 cm. The percentage salable heads was significantly lower with the 28 cm spacing in Experiment I and with the 28 and 33 cm spacing in Experiment II. The percentage grade 1 heads was significantly lower at the 28 and 33 cm spacings in Experiment I and at the 28, 33 and 38 cm spacings in Experiment II than at the wider spacings. Bacterial and fungal disease incidence was higher in the closely-spaced plantings. This was at least partially caused by deceased air movement. For these reasons it would be prudent to maintain at least a 38 cm spacing with 'Nagaoka 55' Chinese cabbage.

Container size and transplant age. Seedling fresh weight increased when the container diameter was increased from 2.5 to

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Table 1. The effect of plant spacing of 'Nagaoka 55' Chinese cabbage on head weight, percent salable heads, and percent grade 1 heads.

Plant spacing cm	Head wt kg	Salable heads %	Grade 1 heads %
	Experiment I (1975–76)		
28	0.85 a[z]	88 a	48 a
33	1.04 b	95 b	78 b
38	1.28 c	96 b	94 c
43	1.50 d	98 b	95 c
	Experiment II (1976–77)		
28	0.70 a	48 a	14 a
33	0.88 b	70 b	28 ab
38	1.06 c	84 bc	44 bc
43	1.25 d	95 c	65 cd
48	1.44 e	99 c	86 d

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

7.5 cm for all transplant ages (Table 2). This implies that seedlings growing in containers with less than 7.5 cm diameter were stunted even when they were 3 weeks old. Seedlings in 5 and 7.5 cm containers were still growing when 6 weeks old whereas seedling growth in 2.5 and 3.75 cm containers had slowed at 3 and 4 weeks, respectively.

Transplanted Chinese cabbage from seedlings in 7.5 cm containers matured 7.5 days earlier than from seedlings in 2.5 cm containers (Table 3). This may be attributed to a larger seedling size, more available moisture, less seedling stunting, less shock and less root binding in the larger containers at transplant time. There was approximately a 2-day decrease in "days to maturity" with the transplants from the 7.5 cm containers when 6-week-old seedlings were used rather than 3-week-old seedlings. No differences in "days to maturity" was recorded with transplants from the smaller 2.5 and 3.75 cm containers. This study is not contradictory with a previous paper (10) because the choice of a maturity date is a biased decision in that it is possible to delay harvest and allow head size to further expand. Therefore, "days to maturity" becomes a more meaningful yield parameter when it is examined along with head weight, salable weight and salable weight/ha/day.

Transplants from 7.5 cm containers produced heads 10 percent heavier than those from 2.5 cm containers when main effect means were compared (Table 4). Transplant age responses were more variable.

Table 2. Growth of 'Nagaoka 55' Chinese cabbage seedlings 3–6 weeks after seeding when growing in cylindrical sleeve containers 6.4 cm deep × 2.25, 3.75, 5, and 7.5 cm diameter. Averages of 2 trials conducted March to May and June to Sept. 1980.

Transplant age (wk)	Mean fresh wt (g/plant)[z] Container diam 2.5 cm	3.75 cm	5 cm	7.5 cm	Mean
3	3.5 i	5.7 i	6.5 hi	13.2 def	7.2 D
4	4.8 i	9.3 fgh	14.3 de	23.1 c	12.9 C
5	6.0 hi	9.8 fgh	17.4 d	35.1 b	17.1 B
6	7.4 ghi	11.5 efg	23.4 c	48.8 a	22.8 A
Mean	5.4 D	9.1 C	15.4 B	30.1 A	

[z]Mean separation of transplant age and container diameter variables (capital letters) and their interactions (lower case letters) by Duncan's multiple range test, 5% level.

Table 3. Mean days from transplanting to harvest of 'Nagaoka 55' Chinese cabbage. Seedlings were raised in cylindrical sleeve containers (6.4 cm deep × 2.5, 3.75, 5, and 7.5 cm diameter) for 3–6 weeks before transplanting during March to May and June to Sept. 1980.

Transplant age (wk)	Time from transplanting to harvest (days)[z] Container diam 2.5 cm	3.75 cm	5 cm	7.5 cm	Mean
	Experiment I (March-May, 1980)				
3	55.5 a	54.5 a	54.5 a	48.5 d	53.3 A
4	55.0 a	54.0 ab	49.0 cd	48.5 d	51.6 B
5	54.5 a	51.5 bc	49.3 cd	47.0 de	50.6 B
6	55.0 a	54.0 ab	49.0 cd	46.0 e	51.0 B
Mean	55.0 A	53.5 B	50.4 C	47.5 D	
	Experiment II (June–Sept 1980)				
3	53.0 abc	53.0 abc	50.8 bcd	49.0 cd	51.4 A
4	56.0 a	49.8 bcd	49.0 cd	47.0 d	50.4 A
5	56.0 a	53.5 ab	50.8 bcd	47.0 d	51.8 A
6	55.3 a	53.5 ab	50.8 bcd	47.0 d	51.6 A
Mean	55.1 A	52.4 B	50.3 C	47.5 D	

[z]Mean separation of transplant age and container diameter variables (capital letters) and their interactions (lower case letters) by Duncan's multiple range test, 5% level.

Salable kg/ha/day is the most meaningful yield index for intensive crop production. Transplant age did not significantly affect kg/ha/day in either experiment when main effect means were compared (Table 5). The yield of plants raised in 7.5 cm containers was 31 and 25% greater in Experiments I and II, respectively, than that of plants raised in 2.5 cm containers. Intermediate results were obtained with plants grown in 3.75 and 5 cm containers. The highest yield achieved was 3.41 metric tons/ha/day in Experiment I with 5-week-old transplants in 7.5 cm containers.

Salable weight (kg/ha) can be calculated by dividing "kg/ha-day" (Table 5) by "days to maturity" (Table 3). Transplant age did not affect salable yield in either experiment when main effect means were compared. The total salable yield of 148 metric tons/

Table 4. Mean head weights of transplanted 'Nagaoka 55' Chinese cabbage at maturity. Seedlings were raised in cylindrical sleeve containers (6.4 cm deep × 2.5, 3.75, 5, and 7.5 cm diameter) for 3–6 weeks before transplanting during March to May and June to Sept. 1980.

Transplant age (wk)	Head wt (kg)[z] Container diam 2.5 cm	3.75 cm	5 cm	7.5 cm	Mean
	Experiment I (March-May, 1980)				
3	2.42 abc	2.56 abc	2.31 bcd	2.44 abc	2.43 A
4	2.34 abcd	2.57 ab	2.55 abc	2.67 a	2.53 A
5	2.40 abc	2.32 bcd	2.48 abc	2.67 a	2.47 A
6	2.03 d	2.23 bcd	2.3 cd	2.35 abcd	2.21 B
Mean	2.30 B	2.42 AB	2.39 AB	2.53 A	
	Experiment II (June–Sept 1980)				
3	1.67 d	1.92 c	1.99 bc	2.41 a	2.00 B
4	2.04 bc	1.94 c	2.23 ab	2.25 ab	2.11 AB
5	2.17 abc	2.15 abc	2.21 abc	2.15 abc	2.17 A
6	2.13 abc	2.02 bc	2.20 abc	2.04 bc	2.10 AB
Mean	2.00 B	2.01 B	2.16 A	2.21 A	

[z]Mean separation of transplant age and container diameter variables (capital letters) and their interactions (lower case letters) by Duncan's multiple range test, 5% level.

Table 5. Salable yield expressed as kg/ha·day of transplanted 'Nagaoka 55' Chinese cabbage. Seedlings were raised in cylindrical sleeve containers (6.4 cm deep × 2.5, 3.75, 5, and 7.5 cm diameter) for 3–6 weeks before transplanting during March to May and June to Sept. 1980.

	Yield (MT/ha·day)[z]				
	Container diam				
Transplant age (wk)	2.5 cm	3.75 cm	5 cm	7.5 cm	Mean
Experiment I (March-May, 1980)					
3	2.62 bcdef	2.67 bcdef	2.49 defg	3.11 ab	2.72 A
4	2.42 efg	2.72 bcdef	3.03 abc	2.86 bcde	2.76 A
5	2.37 fg	2.56 cdefg	2.96 abcd	3.41 a	2.83 A
6	2.10 g	2.50 defg	2.73 bcdef	3.07 ab	2.60 A
Mean	2.38 C	2.61 B	2.80 B	3.11 A	
Experiment II (June–Sept 1980)					
3	1.89 d	2.17 cd	2.22 cd	3.03 a	2.33 A
4	2.07 cd	2.20 cd	2.73 ab	2.50 bc	2.37 A
5	2.33 bcd	2.16 cd	2.49 bc	2.75 ab	2.43 A
6	2.21 cd	2.20 cd	2.53 bc	2.33 bcd	2.32 A
Mean	2.12 B	2.18 B	2.50 A	2.65 A	

[z]Mean separation of transplant age and container diameter variables (capital letters) and their interactions (lower case letters) by Duncan's multiple range test, 5% level.

ha from transplants in 7.5 cm containers was significantly greater than 131 metric tons/ha for transplants in 2.5 cm containers when main effect means were compared in Experiment I. Plants from seedlings in 5 and 7.5 cm containers yielded about 9% greater than those from 2.5 and 3.75 cm containers in Experiment II.

Higher yields compensated for the increased costs associated with raising larger seedlings. Yields were not greatly affected by transplant age within the 3 to 6-week-old range, thus it does not appear to be advantageous to raise seedlings beyond 3 weeks old. A growing period of 3 to 6 weeks does, however, give seedling producers timing and scheduling flexibility in the production of Chinese cabbage seedlings.

Higher yields obtained when larger seedling containers were used may be due at least partially to beneficial effects arising from favorable physical properties of the planting media and availability of fertilizer since the amount of each was proportional to container size. The fertilization regime applied to container-grown seedlings affected the yield of transplanted lettuce (5). Thus, developing an optimized fertilization program for seedlings may substitute for some of the beneficial aspects of a larger container size. This would be a worthwhile future study.

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