The Connecticut Agricultural Experiment Station, New Haven

Chinese Cabbage and Pak Choi Trials 1990

BY DAVID E. HILL

Bulletin 887

March 1991

SUMMARY

During spring and fall 1990, cultivar trials of Chinese cabbage and Pak choi were conducted at Windsor (sandy terrace soil) and Mt. Carmel (loamy upland soil). In two spring plantings the average yield of 18 cultivars of Chinese cabbage at Windsor exceeded 34,000 lb/A in crop 1 and 15,500 lb/A in crop 2. At Mt. Carmel, average yield exceeded 29,000 lb/A in crop 1 and 18,400 lb/A in crop 2. Yield reductions in crop 2 were due to 38% and 12% plant losses by bacterial soft rot at Windsor and Mt. Carmel, respectively. AH603, China Flash, Nerva, and Springtime provided the highest yields and quality in crops 1 and 2 at both sites.

In three fall plantings, the average yield of 13 cultivars in crop 1 was 11,400 lb/A at Windsor compared to 18,000 lb/A at Mt. Carmel. The low average yield at Windsor was due to 49% loss of heads caused by bacterial soft rot compared to 30% at Mt. Carmel. The average yield of 24 cultivars in crops 2 and 3 at Windsor was 26,600 lb/A and 31,100 lb/A compared to 34,200 lb/A and 34,300 lb/A at Mt. Carmel. The lower yield at Windsor in crop 2 was due to a 31% loss caused by bacterial soft rot compared to 20% at Mt. Carmel. Despite heavy losses in fall crop 1 at both sites, satisfactory yields were attained by Chorus and Nerva. In crop 2 at both sites, Chorus, Dynasty and Magica had the highest yield and quality. In crop 3 at both sites, nearly all cultivars performed well.

In spring, the average yield in two crops of five Pak choi cultivars was 22,300 lb/A and 26,200 lb/A at Windsor compared to 21,400 lb/A and 21,600 lb/A at Mt. Carmel. The uniform average yield in both crops at both sites was due to the uniform health of the crops with few losses to bacterial soft rot. Joi Choi, Mei Qing Choi, and What-A-Joy Choi had the greatest yield and highest quality. In fall, the average yield of five cultivars in crop 1 was 7,600 lb/A at Windsor compared to 10,600 lb/A at Mt. Carmel. The low average yield at Windsor was due to 63% loss by bacterial soft rot compared to 31% at Mt. Carmel. In crops 2 and 3 the average yield of seven cultivars was 17,800 lb/A and 22,900 lb/A at Windsor compared to 15,500 lb/A and 10,900 lb/A at Mt. Carmel. Low average yield in crop 3 at Mt. Carmel was due to loss by bacterial soft rot. Joi Choi, Mei Qing Choi and What-A-Joy Choi provided best yield and quality in all fall crops.

The quality of many Chinese cabbage cultivars in spring crop 2 and fall crop 3 at Windsor was degraded by cracking of midribs within the head, a symptom of boron deficiency in the sandy soil at Windsor leached heavily by late-spring and late-fall rains.

Chinese Cabbage and Pak Choi Trials 1990

BY DAVID E. HILL

Chinese cabbage and Pak choi are thought to have originated in China although wild forms have not been found there (Li 1981). Ancient records from the 5th Century BC report that turnip was grown in North China and Pak choi in South China. From the characteristics reported in the 7th Century AD, it appears that early Chinese cabbage forms (ox-stomach cabbage) may have resulted from hybridization between turnips and Pak choi. Since then, culture of Chinese cabbage and Pak choi has spread throughout Asia, where it is now a common vegetable staple surpassed in rank only by rice. Locally, supermarkets report increased sales of Chinese vegetables in the last decade and these sales coincide with the influx of immigrants from the Far East.

Chinese cabbage, *Brassica campestris* var. pekinensis, forms compact barrel-shaped (Napa types), round (Globular type) or elongated heads (Michihli type) with dark-to-light green crinkled leaves and white midribs. Pak choi (Bok choi, Chinese mustard cabbage), *Brassica campestris* var. chinensis, forms a rosette of dark green leaves supported by fleshy, light green to white petioles. (The rosettes will be referred to as "plants" in this report.)

Cultivar testing began in 1988 with a single planting of seven Chinese cabbage cultivars and three of Pak choi. In fall, 11 Chinese cabbage cultivars and three of Pak choi were tested. In 1989, cultivar testing was expanded in spring and fall to 25 cultivars of Chinese cabbage and 11 of Pak choi (Hill 1990). Serial planting was also initiated to determine the duration of harvest and maintenance of quality. In 1990 16 new cultivars of Chinese cabbage were added to the testing program and six were dropped because of poor performance. Two cultivars of Pak choi were added and three were dropped.

In this bulletin, I report yields, quality and maturity of Chinese cabbage and Pak choi cultivars grown at Windsor and Mt. Carmel in the spring and fall of 1990. Strategies to maximize yield and to avoid crop damage by disease and physiological disorders are also discussed.

METHODS AND MATERIALS

Trials were conducted at the Valley Laboratory, Windsor on Merrimac sandy loam and fine sandy loam, terrace soils with somewhat limited moisture holding capacity; and at Lockwood Farm, Mt. Carmel on Cheshire fine sandy loam, a well drained loamy upland soil with a moderate moisture holding capacity (spring crop) and on Watchaug loam, a moderately well drained loamy upland soil with a moderate moisture holding capacity (fall crop). Seeds for the first and second plantings in spring were sown 2 weeks apart in a greenhouse at 50-70 F. Three-week-old seedlings were moved to a cold frame for hardening 7-10 days prior to field planting. The seedlings were transplanted at 18-inch spacing in rows 36 inches apart to provide 9680 plants/A. Each planting consisted of five randomized blocks with six plants per cultivar in each replication. Seeds for the three fall plantings were sown at 2-week intervals in a greenhouse and moved outside 2-3 days after germination. Four-week old seedlings were transplanted in the field at the 5-7 leaf stage.

The seedlings were grown in Promix BX in 36-pot packs, each pot 2-5/8 x 2-1/4 x 2-5/16 inches. Water-soluble 20-20-20 fertilizer (1 Tbsp/gal) was added to the seedlings 1 week before transplanting.

Mature heads of most cultivars were harvested in one picking. The maturity of individual plants of some cultivars was delayed and they were harvested 7-10 days later. The heads were weighed and the quality judged for color, closure and compactness of head. In Tables 2-6, the total yields were calculated by multiplying the plant density (9680) x average head weight x % heads harvested. The planting seasons recommended by the seed companies were followed. If none was listed, cultivars were planted in both spring and fall. Cultivars of Chinese cabbage known to bolt in summer were not grown in the first fall crop.

Seeds were obtained from several domestic and foreign seed companies, some of whom specialize in

Table 1. Soil and crop management of Chinese cabbage and Pak choi, 1990.

ACTIVITY		SPRING CROP	FALL CROP
Soil Fertilization			
10-10-10 (+ Boron at Mt. Carmel)		1000 lb/A	1000 lb/A
Ammonium nitrate		90 lb/A	90 lb/A
(Side dress 2-3 weeks after transplanting)			
Lime (to attain pH 6.5)		None	None
Planting Dates			
Seeding in greenhouse	1st crop	April 2-3	June 18
or outdoor enclosure	2nd crop	April 16	July 2
	3rd crop	-	July 23
Transfer to cold frame	1st crop	April 23	-
	2nd crop	May 6	-
Transplant seedlings to field	1st crop	Apr30-May 2	July 17-19
	2nd crop	May 15-23	Aug 3-9
	3rd crop	-	Aug 29-Sep-1
Pest Control			
Root maggots (at planting)		Lorsban 4E	-
Flea beetles (on seedlings)		Pydrin 2.4E	Pydrin 2.4E, Sevin
Number of Irrigations			
Windsor		1	3
Mt. Carmel		0	2
Weed Control			
Cultivations		2	2

imports from China, Japan and Korea. The varieties selected include representatives of several types of Chinese cabbage and Pak choi grown for summer and/or fall harvest. They are grouped as follows:

Chinese Cabbage

Napa type (barrel-shaped heads)
Large--AH 603, Blues, Chorus, Dynasty, Hanko, Kinakin, Magica, Tango, Tonkin, Wintertime
Medium--Arcadia, China Doll, China Express, China Flash, China Pride, 50 Days, Kasumi, Nagoda, Nerva, Spring Sun 50, Springtime, Spring Triumph, Summertime, TS-1, Two Seasons, WR 60, WR 70

Napa-Michihli Crosses (elongated barrel-shaped heads)
Jade Pagoda, Yoko

Michihli type (elongated cylindrical heads)
Chiko, Green Rocket, Monument

Globular type (round heads)
Small--Tropical 50, Tropical Pride
Miniature--Orient Express

Pak choi

White-stalked type
Large--Joi Choi, Lei Choi, Ming Choi, Prize Choi, What-A-Joy Choi

Green-stalked type
Small--Mei Qing Choi, Shanghai

Details of management of soil and crops and pertinent dates are listed in Table 1. The first spring planting of Chinese cabbage and Pak choi was delayed until April 30-May 2 compared to April 21-24, 1989 to avoid early bolting prevalent in the first spring planting in 1989 (Hill 1990). The third fall planting was intentionally delayed until August 31-September 1 compared to a mid-August planting in 1989. This late planting was scheduled to mature in late-October and early November for evaluation of the effect of early frosts on yield and quality heads.

Uneven rainfall affected development and maturity of Chinese cabbage and Pak choi in 1990. In May, rainfall was nearly 2.75 inches above normal (Brumbach 1965) with long periods of cool, cloudy weather.

Table 2. Yield of Chinese cabbage at Mt. Carmel and Windsor, Spring 1990.

	Mt. Carmel			Windsor		
Cultivar*	Heads Hvst. %	Avg. Head lb	Total Yield lb/A	Heads Hvst. %	Avg. Head lb	Total Yield lb/A
CROP 1						
AH603	90	5.1	44730	97	3.5	32720
Blues	100	4.1	39430	97	3.1	31210
China Doll	100	4.0	39020	97	3.8	35230
China Express	93	3.2	28660	97	3.0	28390
China Flash	100	4.6	44570	100	2.8	27330
50 Days	100	2.9	28070	93	2.6	23290
Hanko	100	4.3	41300	97	4.1	38390
Kasumi	97	3.6	36410	93	3.4	30500
Kinakin	97	3.9	36850	93	3.9	35290
Nerva	97	3.2	30290	100	2.8	27570
Spring Sun 50	100	3.6	34630	100	3.2	31000
Springtime	100	2.7	26340	100	2.9	28400
Spring Triumph	93	4.7	42140	93	3.8	34320
Tango	100	3.9	38180	87	4.0	33790
Tonkin	100	3.1	30110	100	3.3	31800
TS-1	100	3.2	31480	100	3.2	30750
Two Seasons	97	3.3	31270	100	3.0	29040
Yoko	100	3.2	31040	93	3.1	28310
CROP 2						
AH603	57	3.1	17280	93	2.7	23950
Blues	60	2.5	14580	83	2.5	20290
China Doll	77	2.3	17180	90	2.3	19840
China Express	33	2.4	7530	60	2.4	13980
China Flash	87	2.6	22130	90	2.4	21110
50 Days	83	2.9	23660	43	2.4	10150
Hanko	13	3.0	3740	73	2.3	16020
Kasumi	70	2.4	16270	100	2.0	19840
Kinakin	63	2.6	15890	83	2.6	20950
Nerva	93	3.1	28090	83	2.6	20990
Spring Sun 50	80	2.5	19180	87	2.2	18320
Springtime	83	2.8	22400	83	2.1	16850
Spring Triumph	17	1.8	3020	60	2.3	13390
Tango	50	2.9	14080	97	2.6	24340
Tonkin	57	2.7	14930	90	2.4	21300
TS-1	67	2.7	17630	73	2.5	17710
Two Seasons	77	2.1	15350	87	1.9	16340
Yoko	40	2.5	9560	77	1.7	12820

---

* Orient Express and Tropical 50 were 100% bolted in each crop at both sites. China Express, 50 Days, and Spring Triumph were 40-60% bolted at Windsor.

Table 3. Yield of Chinese cabbage at Windsor, Fall 1990.

Cultivar	Crop 1 Heads Hvst. %	Crop 1 Avg. Head lb	Crop 1 Total Yield lb/A	Crop 2 Heads Hvst. %	Crop 2 Avg. Head lb	Crop 2 Total Yield lb/A	Crop 3 Heads Hvst. %	Crop 3 Avg. Head lb	Crop 3 Total Yield lb/A
Arcadia	-	-	-	63	3.0	18030	93	3.3	29060
Blues	50	3.8	18370	57	4.0	22600	90	3.8	32670
Chiko	57	2.1	11720	50	2.4	11840	87	3.1	26120
China Express	-	-	-	70	5.0	34260	80	3.4	26720
China Flash	-	-	-	57	3.7	20510	83	3.6	29100
China Pride	43	2.4	9970	83	4.5	36460	93	3.5	31410
Chorus	70	3.5	23530	90	4.3	37790	97	3.5	33020
Dynasty	37	3.7	13270	67	5.5	35950	97	4.8	45350
Green Rocket	-	-	-	70	2.9	19380	97	2.3	21670
Hanko	33	2.2	7090	80	3.6	28230	100	3.0	28780
Jade Pagoda	37	3.5	12410	50	3.8	18230	87	3.6	29940
Kasumi	-	-	-	83	3.5	28120	100	3.5	33560
Magica	-	-	-	67	5.0	32290	83	3.2	26070
Monument	53	2.5	12770	83	2.4	19060	100	2.9	27790
Nagoda	-	-	-	63	3.8	22890	97	3.0	28130
Nerva	47	2.9	13220	73	4.0	28180	93	3.4	30780
Springtime	-	-	-	60	3.1	18250	83	3.2	25550
Spring Triumph	40	2.2	8670	60	4.4	25870	93	3.6	32710
Tropical Pride	-	-	-	77	3.5	26310	100	2.9	28680
Two Seasons	-	-	-	87	3.1	26010	83	3.0	24280
Wintertime	-	-	-	47	3.9	17870	76	3.7	27350
WR60	13	2.7	3440	60	4.9	28520	90	3.2	27470
WR70	27	2.2	5800	77	4.1	30300	97	3.0	27800
Yoko	53	2.0	10420	73	3.2	22420	97	3.3	31410

In June, temperatures were normal but rainfall was 1.25 inches below normal. Crop 2 planted in mid-May was subjected to heavy leaching rains during early stages of growth. In July, fall planting of crop 1 was subjected to droughty conditions, especially at Windsor, and required three irrigations. Rainfall was 1.5 inches below normal. In August, rainfall was 5.8 inches above normal and subjected the first fall crop to excessive leaching during head formation, especially in the sandy soil at Windsor. October precipitation was also 4.5 inches above normal and again leaching was severe at Windsor. Plants of fall crop 3 at Mt. Carmel were flooded for 3 days following one storm with 3.2 inches of rain. Temperatures in fall were about normal.

YIELD AND QUALITY OF CHINESE CABBAGE

Spring Crops

In crop 1 at Windsor the average yield of 18 cultivars was 18% greater (34,450 lb/A) than at Mt. Carmel (29,060 lb/A). The greater yield at Windsor was due to the development of larger heads (3.6 lb compared to 3.2 lb at Mt. Carmel). Moisture stress in June occurred during the early stages of head development. Irrigation of sandy soil at Windsor but not the loamy soil at Mt. Carmel probably accounted for the increase in head size. Bolting, an important factor that reduced crop yields in 1989 (Hill 1990), was less prevalent in 1990 except for Orient Express and Tropical 50, two small globular types, which

Table 4. Yield of Chinese cabbage at Mt. Carmel, Fall 1990.

	Crop 1			Crop 2			Crop 3		
Cultivar	Heads Hvst. %	Avg. Head lb	Total Yield lb/A	Heads Hvst. %	Avg. Head lb	Total Yield lb/A	Heads Hvst. %	Avg. Head lb	Total Yield lb/A
Arcadia	-	-	-	77	4.5	33520	80	2.8	21840
Blues	70	2.5	16980	67	5.0	32510	93	3.7	33220
Chiko	77	2.2	16060	57	4.0	22170	90	4.2	37030
China Express	-	-	-	80	4.2	32270	93	4.0	36150
China Flash	-	-	-	90	4.5	39140	90	3.8	32910
China Pride	63	3.2	19420	83	4.5	36480	83	4.3	34670
Chorus	67	2.6	17110	77	5.0	37370	97	2.6	24220
Dynasty	60	3.5	20510	80	6.1	47590	90	5.4	47030
Green Rocket	-	-	-	90	3.0	25950	97	2.1	19410
Hanko	63	2.9	17650	73	5.0	35630	100	4.4	42370
Jade Pagoda	53	3.8	19320	83	5.5	43970	93	5.0	44750
Kasumi	-	-	-	80	4.0	31380	93	4.0	36410
Magica	-	-	-	90	5.1	44080	93	3.1	28250
Monument	83	2.0	16410	87	3.7	31540	97	2.5	23880
Nagoda	-	-	-	63	3.7	22750	80	3.3	25590
Nerva	67	2.7	17820	87	3.9	32780	97	3.0	28270
Springtime	-	-	-	60	3.0	17580	93	2.7	23950
Spring Triumph	63	3.3	20300	73	4.8	33690	93	4.3	38880
Tropical Pride	-	-	-	93	2.7	24130	93	2.4	21680
Two Seasons	-	-	-	90	4.5	39550	83	3.4	27460
Wintertime	-	-	-	87	4.6	39030	93	3.2	29320
WR 60	72	3.0	20700	80	4.2	32770	83	4.3	34850
WR 70	57	2.3	12600	73	4.2	29870	80	3.7	28400
Yoko	57	2.9	15980	70	4.2	28270	93	3.1	26970

completely bolted at each site. At Windsor, yields of AH603, China Flash, Hanko, and Spring Triumph exceeded 40,000 lb/A (Table 2). China Express, 50 Days and Springtime yielded less than 30,000 lb/A. Only these cultivars displayed petiole cracking, a symptom of boron deficiency (Takahashi 1981). Kasumi and Two Seasons had moderately poor head closure and compactness. All other cultivars had dense, well-formed heads of excellent quality.

At Mt. Carmel, yields of China Doll, Hanko and Kinikin exceeded 35,000 lb/A. Yields of eight of 16 others exceeded 30,000 lb/A. Despite smaller head sizes at Mt. Carmel, the quality of nearly all cultivars was excellent, notably Nerva, with its very compact head of mild-tasting, succulent leaves. Petiole cracking was not observed at Mt. Carmel and only Kasumi had poor head closure. Although the quality of Hanko was excellent, the head size was variable.

In crop 2 average yields were reduced 55% at Windsor (15,570 lb/A) and 36% at Mt. Carmel (18,458 lb/A) compared to crop 1. The drastic reduction in crop yields was caused by heavy leaching rains during the early stages of crop development and appearance of soft rot in the maturing crop. Thirty-eight percent of crop 2 rotted at Windsor compared to 12% at Mt. Carmel. Losses were due largely to rotting of stems, but at Windsor rotting of leaves within the head was also followed by severe midrib cracking, a symptom of boron deficiency.

At Windsor, the yields of four of 18 cultivars exceeded 20,000 lb/A. Nerva's high yield (28,000 lb/A) and excellent quality was due to the relative absence of soft rot and stem cracking. Tonkin was also free of stem cracking and the quality of surviving heads (57%) was also excellent. All other cultivars showed moderate to severe cracking of midribs.

At Mt. Carmel, the yield of seven of 18 cultivars exceeded 20,000 lb/A. Although the average head weight was only 2.4 lb compared to 3.2 in crop 1, the quality of heads was generally good to excellent, especially China Flash and Kinikin. The low yields of China Express, 50 Days and Spring Triumph were due to 40-57% bolting in those cultivars only at Mt. Carmel.

Fall crops.

The average yield of 13 cultivars in crop 1 at Windsor was 11,400 lb/A compared to 18,135 lb/A at Mt. Carmel. The low average yield at Windsor was due largely to excessive rotting of heads (49%) during rainy August. The average weight of harvested heads was similar (2.8 lb) at both sites. Despite poor crop production at Windsor, the yields of Chorus exceeded 23,000 lb/A (70% harvested) and Blues exceeded 18,000 lb/A (50% harvested) (Table 3). At Mt. Carmel, yields of Dynasty, Spring Triumph and WR 60 exceeded 20,000 lb/A (Table 4). The quality of Dynasty and WR 60 was excellent at both sites. The somewhat loose heads of Spring Triumph were composed of narrow leaves that did not fully overlap.

In crop 2 at Windsor, the average yield of 24 cultivars was 25,670 lb/A compared to 33,660 lb/A at Mt. Carmel. The 22% reduction in yield at Windsor was due to the greater occurrence of soft rot compared to Mt. Carmel (31% vs 20%) and a lower average head weight (4.0 lb vs 4.6 lb). Smaller heads can be attributed to heavy leaching rains in August despite a side dressing of nitrogen 3 weeks after transplanting. At Windsor, the yields of China Express, China Pride, Chorus, Dynasty, Magica, and WR 70 exceeded 30,000 lb/A (Table 3). The yields of 17 of 24 cultivars exceeded 20,000 lb/A. The quality of all harvested heads in all cultivars was excellent.

In crop 2 at Mt. Carmel, the yields of Dynasty, Jade Pagoda and Magica exceeded 40,000 lb/A (Table 4). The quality of the 5-6 lb heads was excellent but the very large head size may confine its marketability to restaurants or institutions. The yield of 17 of 24 cultivars exceeded 30,000 lb/A and the quality of harvested heads of all cultivars was excellent. The seven cultivars whose yields were less than 30,000 lb/A were mostly those with a higher percentage of rotting. Exceptions, however, were Green Rocket and Yoko whose head sizes are characteristically smaller.

In crop 3, the average yield of 24 cultivars was 28,985 lb/A at Windsor and 30,745 lb/A at Mt. Carmel. The increase in average crop yield at Windsor compared to crop 2 (25,670 lb/A) was due to less rotting of heads (8% vs 31%). In fact, the average head weight at Windsor declined in crop 3 (3.3 lb) compared to crop 2 (3.8 lb). At Mt. Carmel, the average yield in crop 3 declined 9% despite less rotting. The decline is due to decreased head weight (3.5 lb) compared to the head weight in crop 2 (4.3 lb) which offset the lower percentage of rotting heads (8% vs 20%).

Although the average yield of all cultivars in crop 3 at Windsor increased 12%, compared to crop 2, the quality of most cultivars was fair to poor due to petiole cracking in October.

Despite severe cracking of petioles in most cultivars, Chorus, Green Rocket, Monument, Springtime, and Tropical Pride showed no petiole cracking. Arcadia, Chiko and Spring Triumph had minor cracking in less than 25% of the crop. Michihli types of Chinese cabbage were more tolerant of boron deficiency than most Napa types. In Windsor, Dynasty had the greatest yield (45,350 lb/A) (Table 3). The yields of seven of 24 others exceeded 30,000 lb/A. Chorus and Spring Triumph had good to excellent quality.

At Mt. Carmel yields of Dynasty, Hanko and Jade Pagoda exceeded 40,000 lb/A (Table 4). Yields of nine others exceeded 30,000 lb/A. The quality of these cultivars was excellent, except Hanko which displayed pepperspot, a black speckling of the midrib. This disorder, said to be associated with nitrite accumulation, is accelerated by fertilizer applications side dressed after head formation (Takahashi 1981). Most cultivars with yields less than 30,000 lb/A had excellent quality except Wintertime, which had poor top closure.

MATURITY

Maturity of Chinese cabbage is important in scheduling planting for a specific harvest period. The days to maturity were calculated from the day of transplanting to the day the heads were harvested. In spring and fall trials 90-100% of each cultivar was harvested in one cutting. In crop 1 in spring, 10% of China Express, China Flash, 50 Days, and TS-1 was harvested in a second cutting 10 days later; Hanko, Spring Triumph and Tonkin, 4 days later.

The days to maturity is dependent upon daylength and weather (Lorenz 1946). In 1990 the average maturity for nine cultivars at Mt. Carmel, common to all spring and fall crops, was 50 days for plants harvested in June, 43 days for early July harvests and 57, 58 and 59 days for harvests in September, October and November. In fall, crops at Windsor matured 4-7 days earlier than Mt. Carmel. In late spring and early summer, plants of Tropical 50 and Orient express matured too rapidly and bolted. Prompt harvest of mature Chinese cabbage in spring is important. Delaying

harvest for 7-10 days reduced the percentage of marketable heads. In fall, with decreasing daylength and temperature, days to maturity increased. Some cultivars, planted late in August at Mt. Carmel, were left in the field as long as 3 weeks beyond maturity without decreasing head quality. Although the outer leaves of some cultivars harvested in late-October and early-November were damaged by frost, their hearts had excellent quality. Although maturity after transplanting varied because of differences in weather and daylength throughout the season, the cultivars can be grouped as follows:

Early (less than 50 days)

AH603, China Express, China Flash, 50-Day, Kasumi, Nerva, Spring Sun 50, Springtime, Tropical Pride, TS-1, Two Seasons.

Middle (50-60 days)

Arcadia, Blues, China Doll, China Pride, Chorus, Green Rocket, Kinakin, Magica, Nagoda, Tango, Tonkin, WR 60, Yoko

Late (greater than 60 days)

Chiko, Dynasty, Hanko, Jade Pagoda, Monument, Spring Triumph, Wintertime, WR 70

YIELD AND QUALITY OF PAK CHOI

Spring Crops

In crop 1, the average yield of five cultivars at Windsor (22,320 lb/A) and Mt. Carmel (21,460 lb/A) differed by only 4% (Table 5). In crop 2, however, the average yield at Windsor (26,220 lb/A) was 17% greater that at Mt. Carmel (21,690 lb/A). Among all cultivars, Joi Choi and What-A-Joy Choi consistently yielded the most. These white-stalked cultivars had excellent quality. The yield of Mei Qing Choi, a cultivar with broad green, spoon-shaped petioles, was low because of its inherent small size, but its quality was high. All plants of Lei Choi and Shanghai bolted, testimony to their sensitivity to cool temperatures and increasing daylength.

Fall Crops

In crop 1, the average yield of four cultivars at Windsor (7,596 lb/A) was 41% less than the average yield at Mt. Carmel (12,915 lb/A). Excessive rain in August profoundly decreased the yield at both sites. Soft rot was observed in 63% of the plants at Windsor compared to 31% at Mt. Carmel. The yields of Joi Choi and What-A-Joy Choi exceeded 17,000 lb/A at Mt. Carmel and What-A-Joy Choi exceeded 12,000 lb/A at Windsor despite 37-77% rotting in each cultivar (Table 6). Ming Choi had the greatest survival rate at both sites (60% and 77%), but its yields were only 7,000-10,000 lb/A. The quality of surviving heads was also highly variable. Bolting of Lei Choi occurred in 80-100% of plants at both sites.

In crop 2, the average yield of six cultivars at Windsor (15,740 lb/A) was 8% less than at Mt. Carmel (17,075 lb/A). The decrease in average yield at Windsor was due to the presence of soft rot in 20% of the plants compared to 5% at Mt. Carmel. The yields of What-A-Joy Choi exceeded 25,000 lb/A at both sites followed by Joi Choi which exceeded 22,000 lb/A. The quality of these white-stalked cultivars was excellent. The yield of Mei Qing Choi was about 9,400 lb/A at both sites. Although the yield of this cultivar is low due to its inherent small size, it is highly prized in oriental cooking. Lei Choi bolted in 80-100% of crop 2.

In crop 3, the average yield of seven cultivars at Windsor (21,465 lb/A) was 87% greater than at Mt. Carmel (11,470 lb/A). The decrease in average yield at Mt. Carmel was due to heavy rains in October which flooded the field for several days and caused soft rot to appear in 15% of the plants compared to only 5% at Windsor. The average plant weight was also smaller at Mt. Carmel. Despite greater rotting at Mt. Carmel, yield of What-A-Joy Choi and Joy Choi exceeded 21,000 lb/A. At Windsor their yields exceeded 25,000 lb/A. At Windsor, yield of the miniature types, Mei Qing Choi and Shanghai Choi, exceeded 15,000 lb/A.

Maturity

In spring and fall trials, each cultivar was harvested in one cutting, attesting to their even maturity. The days to maturity of Pak choi was dependent upon daylength and weather. In spring the average maturity of five cultivars in crop 1 planted May 1-2 for harvest in early June was 37 days at both sites. In crop 2, however, the average maturity at Windsor was 38 days: Mt. Carmel was 29 days. At Windsor, maturity of the crop planted May 15 was delayed compared to crop 1 during the period of cool, wet weather. The planting of crop 2 at Mt. Carmel (May 24), delayed 9 days after Windsor because of heavy rains, matured very rapidly.

In fall, the average maturity of all cultivars in crops 1, 2 and 3 at Windsor was 47, 44, and 40 days compared to 43, 41 and 50 days at Mt. Carmel. Based on 1989 maturities (Hill 1990) a lengthening of maturity of successive fall planted crops was expected. Instead, crops 1 and 2 at both sites were delayed by heavy August rains following transplanting. At Windsor, additional delays were caused by nutrient leaching. Crop 3 at Mt. Carmel matured 10 days later than crop 3 at Windsor, again due to severe flooding of the field following heavy rains in October. Although maturity during the season varied with temperature, rainfall and photoperiod, differences among the cultivars within each crop varied little.

Table 5. Yield of Pak choi at Mt. Carmel and Windsor, Spring 1990.

	WINDSOR			MT. CARMEL		
Cultivar*	Plants Hvst. %	Avg. Plant lb	Total Yield lb/A	Plants Hvst. %	Avg. Plant lb	Total Yield lb/A
CROP 1						
Joi Choi	100	2.2	20990	100	2.2	20910
Mei Qing Choi	100	1.8	17500	100	1.8	17990
Ming Choi	100	1.9	18530	93	1.9	17120
Prize Choi	100	2.4	23680	100	2.2	21780
What-A-Joy Choi	100	3.2	30900	100	3.0	29080
CROP 2						
Joi Choi	93	4.1	36510	100	2.7	26560
Mei Qing Choi	90	2.0	17460	100	1.3	12480
Ming Choi	93	2.9	25900	97	1.8	16610
Prize Choi	90	2.5	22100	93	2.4	21960
What-A-Joy	100	3.0	29360	100	2.8	27550

---

* Lei Choi and Shanghai were 100% bolted in each crop at both sites.

Table 6. Yield of Pak choi at Windsor and Mt. Carmel, Fall 1990.

	CROP 1			CROP 2			CROP 3		
Cultivar	Plants Hvst. %	Avg. Plant lb	Total Yield lb/A	Plants Hvst. %	Avg. Plant lb	Total Yield lb/A	Plants Hvst. %	Avg. Plant lb	Total Yield lb/A
					WINDSOR				
Joi Choi	37	2.6	9460	90	2.7	23640	100	2.8	26860
Lei Choi	0	0	0	0	0	0	77	2.4	18030
Mei Qing Choi	13	0.6	780	63	1.6	9490	90	1.9	17040
Ming Choi	60	1.3	7540	77	1.7	12760	93	2.4	21940
Prize Choi	-	-	-	70	1.9	13170	100	2.6	25430
Shanghai	-	-	-	67	1.5	9730	97	1.7	15840
What-A-Joy-Choi	37	3.5	12540	90	2.9	25650	97	2.7	25800
					MT. CARMEL				
Joi Choi	57	3.1	17320	97	2.4	22460	90	2.5	22180
Lei Choi	20	1.1	2180	23	1.3	2940	13	1.1	1140
Mei Qing Choi	37	1.1	4010	83	1.2	9380	23	1.2	2660
Ming Choi	77	1.4	10060	83	2.1	16510	93	1.5	13200
Prize Choi	-	-	-	93	2.0	18060	73	2.0	13790
Shanghai	-	-	-	73	1.3	9230	47	1.4	6480
What-A-Joy-Choi	77	2.7	20250	100	2.7	25790	90	2.4	21260

---

* Lei Choi was 100% bolted in Crop 1 and Crop 2 at Windsor and 80-90% bolted at Mt. Carmel in all three crops.

MANAGEMENT STRATEGIES

Selection of Cultivars

Chinese cabbage and Pak choi cultivars that can be grown successfully in Connecticut have a fairly narrow range in days to maturity that is mostly controlled by weather and photoperiod. The uniformity of maturity within each cultivar also creates a short harvest span. In 1990, more than 90% of each spring and fall crop at Windsor and Mt. Carmel was harvested within 10 days and is consistent with harvests in 1988 and 1989 (Hill 1990). Thus, multiple cropping seems to be the most practical planting strategy rather than a single planting of several cultivars with a wide range in maturity dates.

In 1988 and 1989, I demonstrated that plantings of Chinese cabbage and Pak choi late in April produced satisfactory yields in June (Hill 1990). Selection of varieties that resisted bolting was highly important for plantings in late April. For early May plantings, the numbers of cultivars that could produce satisfactory yield and quality expanded. In 1990, the spring crops were transplanted in early and mid-to-late May for late-June to early-July harvests. A wide variety of cultivars planted in early May produced satisfactory yield and quality, but many cultivars planted after May 15 were infected with soft rot, a disease that commonly proliferates during moist, hot weather (Kikumoto 1981). The selection of cultivars for spring planting (Table 7) is based on trials during 1988-1990. Yields of cultivars planted in mid-May are generally smaller due to shortened maturity. In spring, the window for planting most cultivars is less than 2 weeks (May 1-10). The planting window expands to 3 weeks for Two Seasons (Apr 20-May 10) and China Flash and Nerva (May 1-20) and to 4 weeks for Blues and Kasumi (Apr 20-May 20). Pak choi cultivars Joi Choi and What-A-Joy Choi provided satisfactory yields and quality in plantings from April 20 through May 20. The small cultivar, Mei Qing Choi, provided excellent yield and quality in plantings from May 1 through May 20.

Mid-July plantings of Chinese cabbage for harvest in mid-to-late August are listed in Table 8. Although not completely immune, these cultivars were most resistant to bacterial soft rot. For August plantings the list of cultivars expands to include virtually all that were tested in 1988-1990. Losses from soft rot in August 1-15 plantings, however, may be expected to reach 20-25%. Losses from soft rot in plantings August 15-September 1 seldom reached more than 8% at both sites. Pak choi cultivars also respond well to cooling fall temperatures. Transplants set in late July for late-August harvest were prone to attack by soft rot. Although Joi Choi and What-A-Joy Choi offered the best resistance, up to 50% loss occurred in these two cultivars. Losses of August transplants of these two cultivars and Mei Qing Choi were less than 10%. Successful planting of Ming Choi was achieved only in late-August.

CONTROL OF PHYSIOLOGICAL DISORDERS AND SELECTED DISEASES

Petiole Cracking

The quality of spring crop 2 and fall crop 3 at Windsor was badly reduced by cracking and browning of petioles. This physiological disorder, a symptom of boron deficiency, can be controlled by adding boron to the soil. At Mt. Carmel, the fertilizer contained trace amounts of boron, and no plants exhibited the symptom. If the fertilizer does not contain trace amounts of boron, the soil can be sprayed with 3 lb soluble boron/A dissolved in water 3 weeks following transplanting.

Pepperspot

Pepperspot, another common physiological disorder may appear following head formation. The small black spots appear on internal leaves as the head forms. The disorder is caused by excess nitrogen in the leaves and nitrite has been detected before the spots are completely formed (Takahashi 1981). Since the disorder may be accentuated by fertilizer side dressing after head formation, it is important to sidedress before the heads begin to form, usually about 3 weeks after transplanting.

Bacterial soft rot

Bacterial soft rot is one of the most destructive diseases of Chinese cabbage (Kikumoto 1981). The soft rot organism, *Erwinia carotovora*, is ubiquitous in the soil. Although complete chemical control is difficult, several management strategies will lessen its importance. The development of the pathogen is enhanced by high temperatures and moisture. This was best demonstrated in our field tests which showed increased mortality of plants in spring crop 2 and fall crop 1. Thus, transplants for early May and mid-to-late-August will be less affected than those transplanted mid-to-late May through July.

If environmental conditions permit, soft rot develops shortly after head formation or 2-3 weeks after transplanting. The pathogen usually enters the stem through the petioles of outer leaves and their scars. Intimate contact of disease-laden soil with the head provides the opportunity for infection. Cultivation for weed control should be before head formation. After head formation, care should be exercised to avoid throwing soil onto the forming head. Soil splash from heavy summer rains can also infect forming heads with the pathogen. Mulching of heading plants with hay or straw has been reported to offer some protection against soft rot (Yoshizawa et al. 1981), especially in summer plantings.

Use of resistant cultivars is the most effective means of controlling soft rot (Kikumoto 1981).

Table 7. Optimum spring planting dates of selected cultivars of Chinese cabbage and Pak choi that provided excellent yield and quality.

April 20-30	May 1-10	May 10-20
CHINESE CABBAGE	CHINESE CABBAGE	CHINESE CABBAGE
Blues	Blues	Blues
Kasumi	Kasumi	Kasumi
Two Seasons	Two Seasons	China Flash
----------	China Flash	Nerva
PAK CHOI	China Express	----------
Joi Choi	Springtime	PAK CHOI
What-A-Joy Choi	AH603	Joi Choi
	China Doll	What-A-Joy Choi
	Hanko	Mei Qing Choi
	Kinakin	
	Nerva	
	Spring Triumph	
	Tango	
	Tonkin	
	TS-1	
	Yoko	

	PAK CHOI	
	Joi Choi	
	What-A-Joy Choi	
	Mei Qing Choi	

Table 8. Optimum fall planting dates of selected cultivars of Chinese cabbage and Pak choi that provided excellent yield and quality.

July 15-30	August 1-15	August 15-30
CHINESE CABBAGE	CHINESE CABBAGE	CHINESE CABBAGE
Blues	Any cultivar	Any cultivar
Chiko	----------	----------
China Pride	PAK CHOI	PAK CHOI
Chorus	Joi Choi	Joi Choi
Dynasty	What-A-Joy Choi	What-A-Joy Choi
Jade Pagoda	Mei Qing Choi	Mei Qing Choi
Monument		Ming Choi
Nerva		
Springtime		
Yoko		

PAK CHOI		
Joi Choi		
What-A-Joy Choi		

Harvesting

Harvest strategy is also clear. Chinese cabbage and Pak choi planted for spring harvests are prone to bolting as daylength increases. The plants should be harvested as soon as they reach marketable size. Delay in harvest of as little as 7 days may result in loss of yield and quality. In fall, as daylength decreases, danger of bolting lessens. Most cultivars of Chinese cabbage and Pak choi could be held in the field for 2-3 weeks without loss of yield and quality. Prolonged cold soil temperature due to excessive spring rain and increasing daylength increases bolting. Excessive rain in summer and early fall promotes outbreaks of soft rot.

I have demonstrated, however, that high yields of marketable quality Chinese cabbage and Pak choi can be obtained in spring and fall by use of cultivars that resist bolting and disease. Management practices can also be adjusted to minimize physiological disorders and diseases that are common to the crops.

The suitability of Chinese cabbage and Pak choi as a new crop for Connecticut is appealing because of an expanding market, ease of growing, and high yield. Their short maturity makes them especially useful for crop succession throughout the growing season. Early Chinese cabbage and Pak choi plantings can be harvested in early-to-mid June, allowing sufficient time to plant other crops for fall harvest. They are also ideal for serial cropping up to September 1 for late fall harvests that withstand mild frosts in October and early November.

REFERENCES

Brumbach, J.J. 1965. The climate of Connecticut. Bull. 99. State Geological and Natural History Survey of Connecticut. 215 p.

Hill, D.E. 1990. Chinese cabbage and Pak choi trials--1988-1989. The Connecticut Agricultural Experiment Station, New Haven. Bull. 879. 12 p.

Kikumoto, T. 1981. Studies on softrot disease of Chinese cabbage in Japan. *In*: Chinese cabbage. Proceedings First International Symposium. Talekar & Griggs, Eds. AVRDC Pub. No. 81-138. 439 p.

Li, C.W. 1981. The origin, evolution, taxonomy and hybridization of Chinese cabbage. *In*: Chinese cabbage. Proceedings First International Symposium. Talekar & Griggs. Eds. AVRDC Pub. No. 81-138. 439 p.

Lorenz, O.A. 1946. Response of Chinese cabbage to temperature and photoperiod. Proceedings of American Society for Horticultural Science. 47:309-319.

Takahashi, K. 1981. Physiological disorders in Chinese cabbage. *In*: Chinese cabbage. Proceedings First International Symposium. Talekar & Griggs. Eds. AVRDC Pub. No. 81-138. 439 p.

Yoshizawa, T., Ma, C.H., & Roan, Y.C. 1981. Management of summer Chinese cabbage in Taiwan. *In*: Chinese cabbage. Proceedings First International Symposium. Talekar & Griggs. Eds. AVRDC Pub. No. 81-138. 439 p.

The Connecticut Agricultural Experiment Station, founded in 1875, is the first experiment station in America. It is chartered by the General Assembly to make scientific inquiries and experiments regarding plants and their pests, insects, soil and water, and to perform analyses for State agencies. The laboratories of the Station are in New Haven and Windsor; its Lockwood Farm is in Hamden. Single copies of bulletins are available free upon request to Publications; Box 1106; New Haven, Connecticut 06504.

ISSN 0097-0905