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THE EFFECT OF SIZE, PARTIAL DEFOLIATION, AND USE OF PROTECTIVE ROW COVERS ON THE QUALITY AND YIELD OF CHINESE CABBAGE (BRASSICA CAMPESTRIS L. SSP. PEKINENSIS)

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By

Vincent Arthur Fritz

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ABSTRACT

THE EFFECT OF SIZE, PARTIAL DEFOLIATION, AND USE OF PROTECTIVE ROW COVERS ON THE QUALITY AND YIELD OF CHINESE CABBAGE (BRASSICA CAMPESTRIS L. SSP. PEKINENSIS)

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Protective wax paper tunnels, used in early celery production in Michigan were utilized to prevent bolting in Chinese cabbage (*Brassica campestris* L. ssp. *Pekinensis*). The transplants were subjected to various degrees of defoliation (0, 25, 50% of the foliar length) to achieve minimal transplant shock. Various plant sizes (3-4, 5-6, 7-8 leaf stages) were also examined to confirm the report that cold temperature sensitivity changes with plant size.

Severely pruned (50%) plants were slow in recovery from transplant shock as compared to those unpruned and slightly pruned (25%). Unpruned plants showed good early plant growth. Early plant growth under tunnels was more rapid than without tunnels. The tunnel was effective in preventing vernalization and bolting. 3-4 leaf transplants recovered more slowly than larger transplants (5-6 and 7-8 leaves). The 5-6 and 7-8 leaf stage transplants produced the largest head weights.

DEDICATION

The author wishes to dedicate this thesis to his wife, Barb, for her endless love, support, and understanding throughout his graduate studies.

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The author wishes to express sincere appreciation to Dr. S. Honma for his valuable assistance in experimentation and in the preparation of the manuscript. Appreciation is also extended to Dr. H.C. Price and Dr. D. Warncke for their suggestions and constructive criticism of the manuscript.

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INTRODUCTION

Chinese cabbage (*Brassica campestris*, L. ssp. *pekinensis*), originated from *Brassica campestris* and was first reported in China between 290 and 307 AD (Kraus, 1940). Sturtevant (1919) reported that it had been identified in several art works of agriculture as early as the fifth century. It was introduced into Europe in 1751 by missionaries (Boswell, 1949). Cultivation of Chinese cabbage in the United States was essentially nonexistent until about 1884 when interest in this vegetable increased. Bailey (1930) imported several cultivars from Kew in 1893 and from Japan in 1890-1894. According to Fairchild (1918), there were substantial plantings of Chinese cabbage in New Jersey for many years prior to his writing.

Chinese cabbage production in Michigan is limited, but may increase with the continuing influx of Asiatic people into the United States and the increase in the number of American consumers. Other reasons for the limited production of Chinese cabbage may be due to the lack of knowledge in culture and its culinary use.

Chinese cabbage requires close attention since it is extremely sensitive to environmental conditions. It is susceptible to severe shock at transplanting due to its limited root system and massive leaf area. The plant's transpiration rate is escalated when exposed to high temperatures, low relative humidity, and wind so provisions must be made to supply water. Chinese cabbage is also very sensitive to cold temperatures and will easily bolt. Approximately two weeks exposure to temperatures at or below 13°C will induce flowering (Koda et al., 1974). This process inhibits the head formation when the plants are young and decreaess the value of the crop at maturity. Japanese growers use 91 cm (3 ft.) wide polyethylene film tunnels for early production. Celery growers in Michigan use a white plastic or wax paper tunnel to allow for warming during the day to reverse the vernalization process.

The purpose of this study was to determine whether the tunnels used in the production of celery can be applied to an early crop of Chinese cabbage. Other factors such as partial defoliation, seedling stage, and methods of growing transplants were also examined.

LITERATURE REVIEW

Several studies have been conducted relating to early maturity and increased yields in vegetables. Early maturity has been accomplished by the use of transplants, however, there is concern of seedling damage caused by adverse weather conditions or simply by the physical act of transplanting. Partial defoliation has been used to reduce transpiration, thus reducing transplant shock. This allows for root establishment during the early stages of growth after transplanting. Van Graan (1929) reported that by removing some of the foilage of a celery seedling, the remaining portion of the leaves would remain photosynthetically efficient for a longer period during the day. He also found that pruned cabbage and tomato seedlings matured earlier, but only following exposure to adverse environmental conditions. Zink and Knott (1965) found that pruned vegetable seedlings were in no instance superior to unpruned plants in terms of earliness or yield. They also reported that the least pruned seedlings recovered better from transplanting and there was no significant difference in percent survival between the pruned and unpruned plants. Kraus (1942) working with cauliflower seedlings, noted that the total loss of water was greater for the unpruned than the pruned, but the rate of transpiration was greater per unit leaf area for the pruned than the unpruned plants. He also noted that transplant recovery and subsequent root and top growth was correlated with the amount of carbohydrates present after pruning. This is in agreement with Aung and Kelly (1966), who reported that young leaf defoliation in tomato resulted in a decrease of the net assimilation rate due to the loss of the carbohydrate sink supplied by the young leaves. Defoliation of mature leaves resulted in a subsequent increase in new growth. This increase rate of new growth appeared to be made because of a reduction in the relative growth of the stem and roots. They suggested that this was due to a redirection of translocates from the stem and roots to the apex.

The use of various sizes of transplants at transplanting is also used to overcome the check in growth. Zink and Knott (1965) reported that extra large and large celery plants (graded on a fresh weight basis) produced significantly higher yields than smaller transplants. No significant difference in plant survival was observed. However, Kratky, Wang and Kubojiri (1982) found that various transplant ages of Chinese cabbage had a minimal affect on days to maturity and no affect on yield when grown in an unheated plastic greenhouse.

Seedling stage is very important in preventing premature flowering in Chinese cabbage. Eguchi et al. (1963), Iwama and Serizawa (1953), and Yamasaki (1962) reported that the susceptibility to low temperatures augments with seedling age. Wang (1969), and Kagawa and Soda (1957) found that 12 day old seedlings of <u>Brassica</u> <u>chinensis</u> when exposed to 10° C for 3 days bolted 10 days later when exposed to high temperatures and long daylengths. Lorenz (1946) also reported similar results with Chinese cabbage. Nakamura (1976) and Koda et al., (1974) reported that Chinese cabbage seedlings having approximately 20-25 outer leaves will form a head even if vernalized since enough leaves were differentiated to permit proper head formation prior to bolting. Yamasaki (1956) reported that 30 day or older (7-8 leaves) seedlings, have enough differentiated leaves to properly form the head following vernalization. Nakamura (1976), Koda et al.(1974), and Cooley (1979) stress that proper growing conditions must be maintained to overcome the competition between flower stalk formation and leaf growth, so that head formation can be completed.

One cultural method that has been used to ensure the proper environmental conditions for plant growth has been the use of protective coverings. These are made of plastic, paper, waxed paper, and nylon mesh. Opena (1981) and Harris (1965) reported that the interval from seedling to emergence decreased and the percent emergence increased giving a more uniform crop when sown under a protective tunnel. Bakhchevanova (1976) found that by using plastic tunnels for spring cabbage production, earliness increased 203.1%, overall yield 14.8%, and total value of the crop 20.4%. O'Dell (1979) obtained similar results with peppers as did Malakowski (1969) with carrots, radishes, cauliflower, cucumbers, and melons. However, Zink (1954) in California did not obtain a higher yielding or earlier crop of muskmelons and reported that very high temperatures in the plastic tunnels damaged the plants. This is in agreement with Wells and Loy (1980) who found that vine crops perish from excessive transpiration if a decrease in soil temperature occurs due to cloudy weather followed by sunny days. The use of perforated or slit tunnels was used to help alleviate the problem of high temperatures. Slitted tunnels were preferred because of its superior ability to retain more heat at night when the wind is usually calmer. This also helps to keep the humidity and condensation from causing damage. High air temperature is of concern when growing Chinese cabbage. Marukawa (1975) found no growth inhibition when temperatures reached 30-32°C, however, Nakamura (1976) and Koda et al., (1974) warn that high temperatures increases susceptibility to soft rot (*Erwinia caratovora*).

Frost protection is another benefit of protective coverings. Waggoner (1958) and Zink (1965) found that plastic had both a higher maximum and a lower minimum temperature than the paper cover. The use of protective coverings in spring Chinese cabbage production is important in preventing frost as well as inhibiting vernalization.

Bremer (1935) and Kraus (1940) felt that there were other factors affecting bolting. Lorenz (1946) found that exposure for one month to 8°C and long days greatly hastened flowering. According to Nakamura (1976) and Koda et al., (1974) many commercial varieties will initiate a flower primordia if exposed for 14 days to 5°C. Yamasaki (1956) developed a formula to determine when sufficient vernalization has occurred: $(13-X)\ Y \geq 87°C$, X=temperature below 13°C and Y=number of days with a minimum daily temperature below 13°C. When the heat sum of the low temperature reaches or exceeds 87°C, flower induction takes place. It follows that the longer the duration of the cold treatment, the sooner flowering will occur. Mori et al., (1979), Iwama and Serizawa (1953), Nakagawa (1957), and Thompson (1929) all reported similar results.

MATERIALS AND METHODS

Horticulture Research Center, Spring 1979

A preliminary study was made to determine the effect of partial defoliation of the transplant on yield, head length, head diameter, and flower stalk development. The transplants were grown in 6 cm Jiffy peat pots and in greenhouse soil.

Seeds of Nagaoka #2 were sown in standard wooden flats (51 x 90 x 8 cm) using a 1:1:1 top soil, peat, sand mixture on March 23. One week later, the seedlings were thinned to 35 plants per flat. The plants were fertilized weekly with 113.5 gms of 6-24-30 and 113.5 gms of ammonium nitrate in 8 litres of H_2O using a 16:1 garden hose proportioner. The experiment consisted of 6 treatments in randomized complete block design with 9 plants per treatment and 2 replicates. The treatments were: (a) 3 degrees of defoliation of 0, 33, and 66% of the foliar length; (b) transplants grown in peat pots, and bare rooted transplants.

On May 7 the transplants with 7 true leaves were transplanted in the field. The 7 leaf stage has been reported to be at the optimal stage to permit completion of the heading process prior to flower stalk elongation (Yamasaki, 1956).

Spacing within the rows was 38 cm and between rows was 61 cm. After transplanting, all plants were watered with 120 ml of a starter solution and insecticide (Diazinon) mixture. The plot was irrigated, sprayed, and cultivated as necessary. A preplant application of 1135 kg per hectare of 12-12-12 was applied. Two side dressings of ammonium nitrate at 113.5 kg per hectare were also applied prior to and during the heading process.

The Chinese cabbage was harvested from June 27 to July 6. Plant yield, head length and diameter, and number of visible flower stalks were recorded.

Greenhouse, Fall 1979

An experiment was conducted in a greenhouse bed to determine the effect of various number of leaves on the transplants and the amount of defoliation on yield, head length and diameter. The transplants were grown as in the previous experiment. Seeds of Nagaoka #2 were sown in flats on 7/23, 7/27, 7/31 and 8/4 to obtain the various leaf numbers necessary. Plants were selected for leaf number rather than chronological age due to uneven growth within each sowing. The non-uniformity in plant growth made it necessary to transplant at various times (8/27, 8/29, and 9/1). The experiment was a randomized complete block design with 9 plants per treatment and three replicates. The treatments consisted of three degrees of defoliation: 0, 25, and 50% of the plant foliar length, applied to 4, 5, 6, and 7 leaf stages. Spacing was 38 cm within rows and 61 cm between rows in a greenhouse bed. Two side dressings of 227 gms of ammonium nitrate in 16 litres of H_2O using a 16:1 garden hose proportioner were applied in addition to a preplant application of fertilizer based on a soil test. Daytime temperature was maintained at 20-25°C at the beginning of the experiment and at 15-18°C towards harvest. Chinese cabbage was harvested from 10/27 to 11/7. Head weight, head length and diamter were recorded.

Horticulture Research Center, Spring 1980

Due to the difficulty in obtaining precise leaf stages, plants with 3-4, 5-6 and 7-8 leaves are used for this experiment. Plants with 0, 25 and 50% of the foliar length removed were grown with and without protective covering. The protective covering was a wax paper tunnel which enclosed a single row of plants.

Seed of Nagaoka #2 were sown in flats using a 1:1:1 soil, peat, sand mixture at weekly intervals starting on 4/1. The seedlings were fertilized as in the previous studies. On 5/5, seedlings were transplanted bare rooted in the field fertilized with 1135 kg per hectare of 16-16-16 and preplant incorporated with a herbicide (trifluralin) at 908 gms of active ingredient per hectare. The experimental design was a split plot with 20 plants per treatment and 4 replicates. Each leaf stage was subjected to the 3 degrees of defoliation at the time of transplanting. The protective tunnel was applied the following day due to windy conditions. After transplanting, all plants were treated with a starter solution and insecticide (Diazinon). The plot was irrigated, sprayed, and cultivated as necessary. Thermocouples were placed within each plot in pairs to monitor the rising and falling air and soil temperatures within and outside the protective tunnels. The soil thermocouple was placed 10 cm below the soil surface and the thermocouple 10 cm above the soil surface. Temperatures were recorded from 5 a.m. to 10 p.m. and from 12-1 a.m. The tunnels were vertically slit every 60 cm due to high internal air temperatures (>35°C) one week later. Tunnels and the thermograph were removed on 5/21. The number of visible leaves were recorded on 5 randomly selected plants in each treatment of the 4 replicates 2 days after the tunnels were removed. Harvesting began on 6/26 and continued until 7/1. Head weight, head length and diameter, internal flower stalk length, number with visible flower stalks, and percentage of harvestable plants were recorded.

Horticulture Research Center, Muck Farm, Spring 1981

Two experiments were conducted in the spring, one at the Horticulture Research Center (HRC) and the other at the Muck Farm. The plants were transplanted on 4/27 at the HRC and on 4/29-30 at the Muck Farm in order to expose the plants to cold temperatures for a longer duration than the previous spring. The experimental design was similar to that used in the spring of 1980, except 10 plants per treatment with 3 replicates and 2 varieties were used. The varieties Nagaoka #2 (Won Bok type) and Jade Pagoda (Chihili type) were selected for these plantings. The HRC plot (sandy loam) was fertilized with 1135 kg per hectare of 16-16-16 and preplant incorporated with a herbicide (trifluralin) at 908 gms active ingredients per hectare before planting. The Muck Farm plot (organic soil) was fertilized with 1135 kg per hectare of 5-10-30. No herbicide was applied on the organic soil. Two side dressings of potassium nitrate at a rate of 113.5 kg per hectare were applied to both plots prior to heading and again two weeks later.

Since the recording thermograph previously used was unavailable, minimum-maximum thermometers were placed in the plots in pairs 10 cm above and below the soil surface. Air and soil temperatures were recorded both inside and outside the tunnels until the tunnels were removed on 5/27 at the HRC and on 5/28 at the Muck Farm. Vertical slits were made to the wax paper coverings when air temperatures exceeded 35°C. Harvesting at HRC of Nagaoka #2 began on 6/29-30 and from 7/6-7 for Jade Pagoda. The Muck Farm was harvested from 7/8-12 for Nagaoka #2 and from 7/15-17 for Jade Pagoda. Data were obtained for head weight, head length and diameter, internal flower stalk length, number of visible flower stalk, and percentage of harvestable plants. Data from all experiments were analyzed statistically using analysis of variance, least significant difference and trend analysis.

RESULTS AND DISCUSSIONS

Peat Pot and Pruning Study, Spring 1979

Harvesting began at the Horticulture Research Center (sandy loam) on 6/27 and continued until 7/6. There were no significant differences in head length and diameter due to the degree of defoliation (0, 33, 66% of the foliar length) for plants transplanted bare rooted and in peat pots. Head weight and percentage of bolters were also uneffected by the treatments. Although main treatment effects and interactions were not significant, the data showed the following trends: both unpruned peat pot and bare rooted transplants developed heads that were larger in diameter, higher in head weight, and with fewer number of bolters than the pruned plants. Within the defoliation treatments, the peat pot transplants produced head weights that were slightly larger than or equal to the bare rooted plants (Table 1).

Pruning and Leaf Stage Study, Fall 1979

Harvesting began in the greenhouse on 10/27 and continued until 11/7. Statistical analysis of main treatment effects (leaf stage and pruning) suggested that head length was not effected. Head diameter was significantly effected

TABLE 1: EFFECTS OF PARTIAL DEFOLIATION AND TYPE OF TRANSPLANT ON YIELD AND QUALITY OF CHINESE CABBAGE (CV. NAGAOKA #2), HRC, 1979[1]

	Degree of Defoliation (%)	Head Length (cm)	Head Diameter (cm)	Head Weight (kgms)	% Bolted
Bare Rooted	0	27.6	14.7	1.22	10
	33	26.2	14.6	1.10	65
	66	26.5	14.5	1.10	17
Peat Pot	0	26.7	15.0	1.27	11
	33	27.0	14.4	1.19	19
	66	26.5	14.2	1.10	19

[1] Mean differences not significant at the 10% level

by a leaf X pruning interaction ($P = .001$). Trend analysis of this interaction suggested a quadratic trend at the 6 leaf stage, with the slightly (25%) pruned plants producing the smallest head diameter ($P = .05$) (Figure 1). At the 7 leaf stage, head diameter decreased linearly with increased pruning ($P = .001$).

Plants that were transplanted at the 7 leaf stage produced heads smaller in head weight when compared to 4, 5, or 6 leaf stage plants ($P = .001$) (Table 2). Head weight differences between 4, 5 and 6 leaf stage plants were not significant. The lower head weights produced by the 7 leaf stage plants may be attributed to slower transplant recovery due to root damage and subsequent inadequate water uptake. Loomis (1925) found that plants seriously injured by transplanting have a high rate of top growth and slow rate of root replacement. He also noted that transplant injury increased with advancing maturity. The present study shows that the slightly (25%) and severely (50%) pruned transplants produced lower yields than unpruned plants ($P = .001$) Table 2). This may be due to reduced photosynthetic efficiency as well as a decrease in leaf area. The differences in head weight between slightly (25%) pruned and severely (50%) pruned plants was not significant.

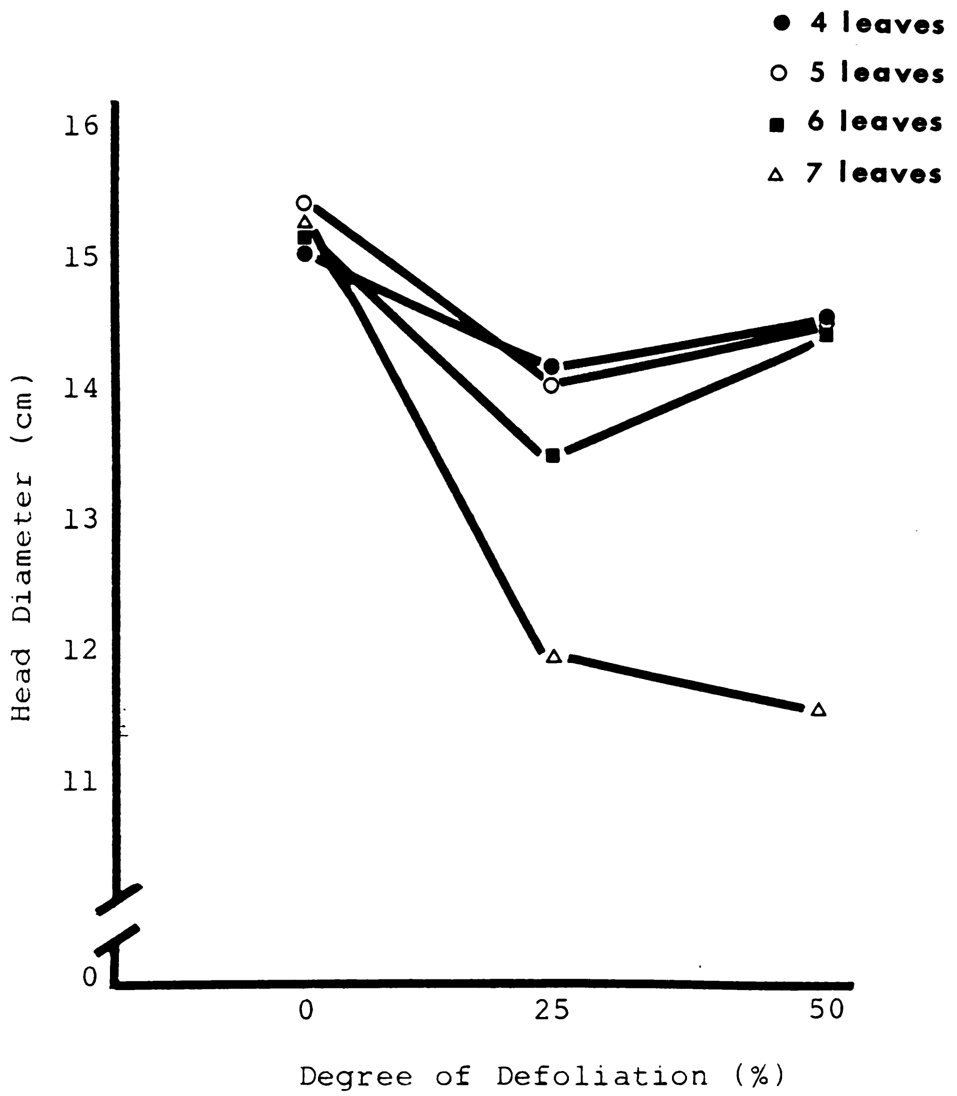


FIGURE 1: THE EFFECT OF DEGREE OF DEFOLIATION AND TRANSPLANT LEAF STAGE, ON HEAD DIAMETER OF CHINESE CABBAGE (CV. NAGAOKA #2), GREENHOUSE, 1979

TABLE 2: EFFECTS OF TRANSPLANT LEAF STAGE AND DEGREE OF DEFOLITATION ON HEAD LENGTH, DIAMETER, AND WEIGHT OF CHINESE CABBAGE, (CV. NAGAOKA #2), GREENHOUSE, 1979

Parameter	Leaf Stage					Degree of Defoliation(%)			
	4	5	6	7	LSD	0	25	50	LSD
Head Length (cm)	23.7	23.6	23.5	24.0	n.s.	23.9	23.4	23.9	n.s.
Head Diameter (cm)	14.6	14.6	14.3	12.9	n.s.	15.1	13.5	13.7	n.s.
Head Weight (kgms)	1.22	1.22	1.17	.94	.19*	1.30	1.04	1.08	.17*

N.S. - Not Significant at 10% level

* - Significant at .1% level

Tunnel, Leaf Stage, and Pruning Study, Spring 1980

Protective wax paper tunnels placed over different size transplants that were pruned at various degrees of defoliation (0, 25, 50%) were removed due to extremely high temperatures two weeks after installation. Leaf stages used were 3-4, 5-6, and 7-8 leaves. After the tunnels were removed, leaf number count was made from 5 randomly selected plants in each treatment to determine the effect of the tunnel on the growth rate. All 3 main effects (tunnel, leaf stage, and pruning) significantly affected early plant growth (P = .01, .001, and .001 respectively) (Table 3).

The tunnels may have increased growth over the unprotected plants due to increased air and soil temperatures. The unprotected plants, which were exposed to the wind, may have had a higher leaf water deficit than the protected plants. It has been hypothesized (Winter, 1965) that this reduced the rate of water loss (because of stomatal closure) but maybe interfered with gas exchange, photosynthesis, and growth.

The smaller transplants (3-4 leaves) produced significantly smaller size plants than the larger transplants (5-6 and 7-8 leaves) (P = .001). It was noted after tunnel removal that the severely (50%) pruned plants were smaller than unpruned or slightly (25%) pruned plants (P = .001) (Table 3).

Fifty-two days after transplanting the heads were harvested. Head length was not significantly effected by the

TABLE 3: EFFECTS OF TRANSPLANT LEAF STAGE, DEGREE OF DEFOLIATION, AND PROTECTIVE COVERS, ON QUALITY AND YIELD OF CHINESE CABBAGE, (CV. NAGAOKA #2), HRC, 1980

Parameter	Leaf Stage				% Defoliation				Cover		
	3-4	5-6	7-8	LSD	0	25	50	LSD	Yes	No	LSD
Plant size (# leaves)	6	8	8	.4****	8	8	7	.4****	9	7	.6***
Head Diameter (cm)	14.9	15.6	15.3	.5**	15.3	15.3	15.2	n.s.	15.2	15.3	n.s.
Head Length (cm)	20.7	21.1	20.8	n.s.	20.9	20.8	20.8	n.s.	20.4	21.3	n.s.
Head Weight (kgms)	1.32	1.52	1.47	n.s.	1.45	1.44	1.41	n.s.	1.40	1.47	n.s.
Internal Stalk (cm)	9.3	9.8	9.5	n.s	9.8	9.4	9.3	n.s.	8.2	10.7	1.0*
Percent Harvested	65	80	80	10***	80	75	75	n.s.	75	75	n.s.

n.s. - not significant at 10% level
* - significant at the 10% level
** - significant at the 5% level
*** - significant at the 1% level
**** - significant at the .1% level

treatment main effects or interactions and although head diameter was effected by leaf stage (P = .05), the mean differences between treatments was $<$ 1 cm.

The role of leaf stage in effecting head weight was dependent on whether the transplants were protected. A tunnel X leaf stage interaction showed a linear-quadratic relationship for the unprotected plants (Figure 2) (P = .005). The smaller transplants (3-4 leaf stage) were inferior to the 5-6 and 7-8 leaf stages and the head weight of the 7-8 leaf stage plants was less than the 5-6 leaf plants. The protected plants showed similar trends but were not significant. The small (3-4 leaves), unprotected plants were inferior to the 3-4 leaf stage plants under the tunnels. This may be due to the small plants being more susceptible to transplant shock. This is also discernible from the differences in percentage of harvestable plants due to leaf stage (Table 3). The 3-4 leaf stage showed a lower percentage of harvestable plants at the end of the experiment than the other leaf stages (P = .01). Zink and Knott (1965) found that small celery transplants recovered more slowly than larger plants. All other treatment main effects (tunnel and pruning) and interactions did not affect the harvestable percentages.

Although the protected plants were larger at the time of tunnel removal, the post tunnel growth rate appeared to be reduced. This may be due to rapid growth under the tunnels

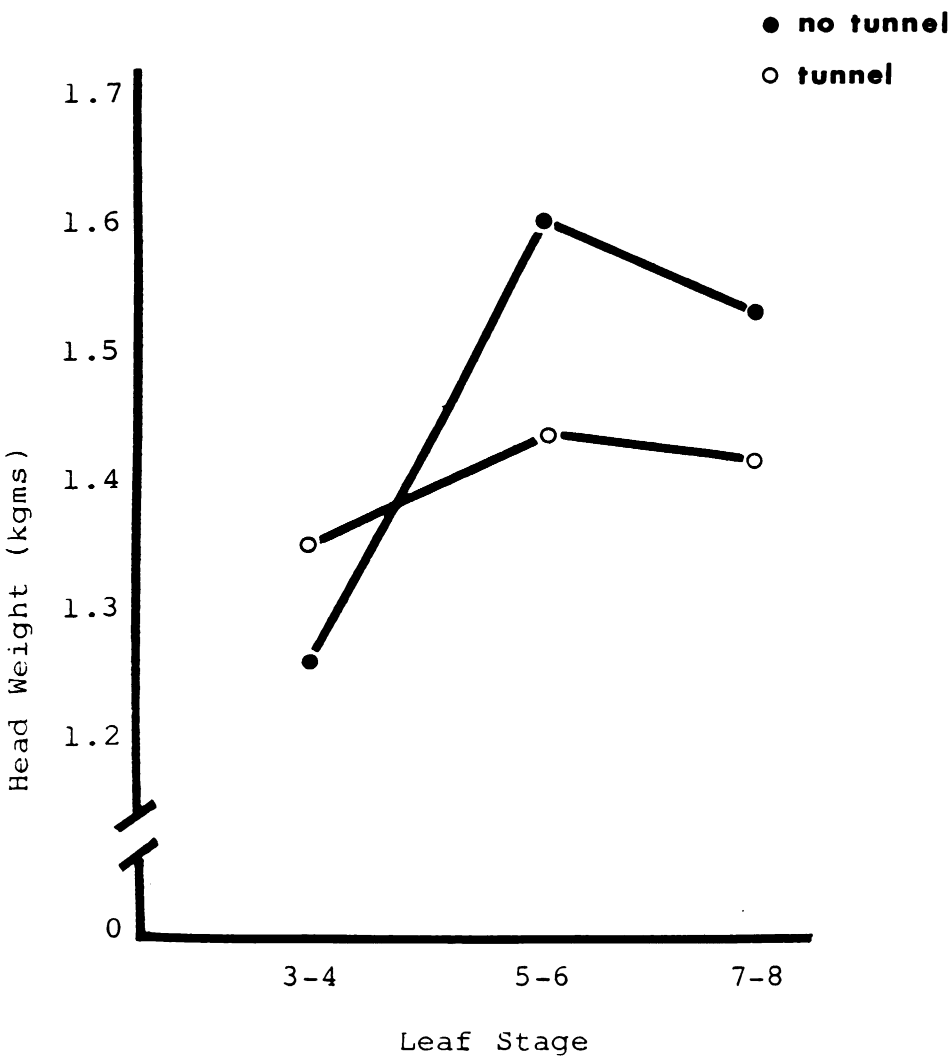


FIGURE 2: THE EFFECT OF TRANSPLANT LEAF STAGE AND PROTECTIVE COVERS, ON HEAD WEIGHT OF CHINESE CABBAGE (CV. NAGAOKA #2), HRC, 1980

which made these plants succulent and sensitive to a more adverse environment. Similar observations were made by Waggoner (1958) who reported that following cover removal on tomatoes, the plants became less vigorous and set less fruit. Harris (1965) reported similar results with corn and beans.

Due to a warm spring, flower stalks were not visible at harvest. In order to evaluate the effect of the tunnel on bolting, each harvested head was cut longitudinally, and the length of the developing stalk was measured. The presence of the internal flower stalks indicated that the plants received the minimal amount of cold temperatures for vernalization. The unprotected plants showed a longer internal stalk than the protected plants (P = .10) (Table 3).

From this experiment, one may conclude that the larger transplants (5-6 and 7-8 leaf stages) produced heads that were superior to the 3-4 leaf transplants. In general, pruning the seedlings adversely effected early plant growth but did not significantly decrease yield. If the plants were transplanted earlier to new exposed or colder temperatures for a longer period, the unprotected plants probably would have produced significantly more bolters than those plants protected. This would have resulted in decreased tonnage per hectare.

<u>HRC, Nagaoka #2, Spring 1981</u>

Nagaoka #2 was harvested on 6/29-30. Statistical analysis suggested that none of the main treatment effects (leaf stage, pruning, tunnel) significantly affected head diameter, head length, or head weight. The percentage of harvestable plants was effected by leaf stage (3-4, 5-6, 7-8). The 7-8 leaf transplants produced slightly more harvestable heads than the 3-4 leaf stage plants (P = .10) (Table 4). There was no significant difference in the number of harvestable plants between 5-6 and 7-8 or 3-4 and 5-6 leaf stages. The percentage of bolters was significantly effected by a tunnel X leaf stage interaction (P = .025). Trend analysis suggested that for the unprotected plants, the percentage of bolters linearly decreased with increased transplant size (P = .01) (Figure 3). For the protected plants, the percentage of bolters increased with larger transplant size, however, it was not significant. The unprotected plants had internal flower stalks that were slightly longer than plants grown under tunnels (P = .10) (Table 4).

HRC, Jade Pagoda, Spring 1981

Plants were harvested one week later than Nagaoka #2 (7/6-7). The main treatment effects (leaf stage, pruning, tunnel) had no effect on head diameter, head lenght, internal stalk length, or head weight, however the use of the tunnels did significantly reduce the percentage of bolters (P = .05), (Table 5) resulting in a higher percentage of harvestable plants (P - .10). The percentage of plants

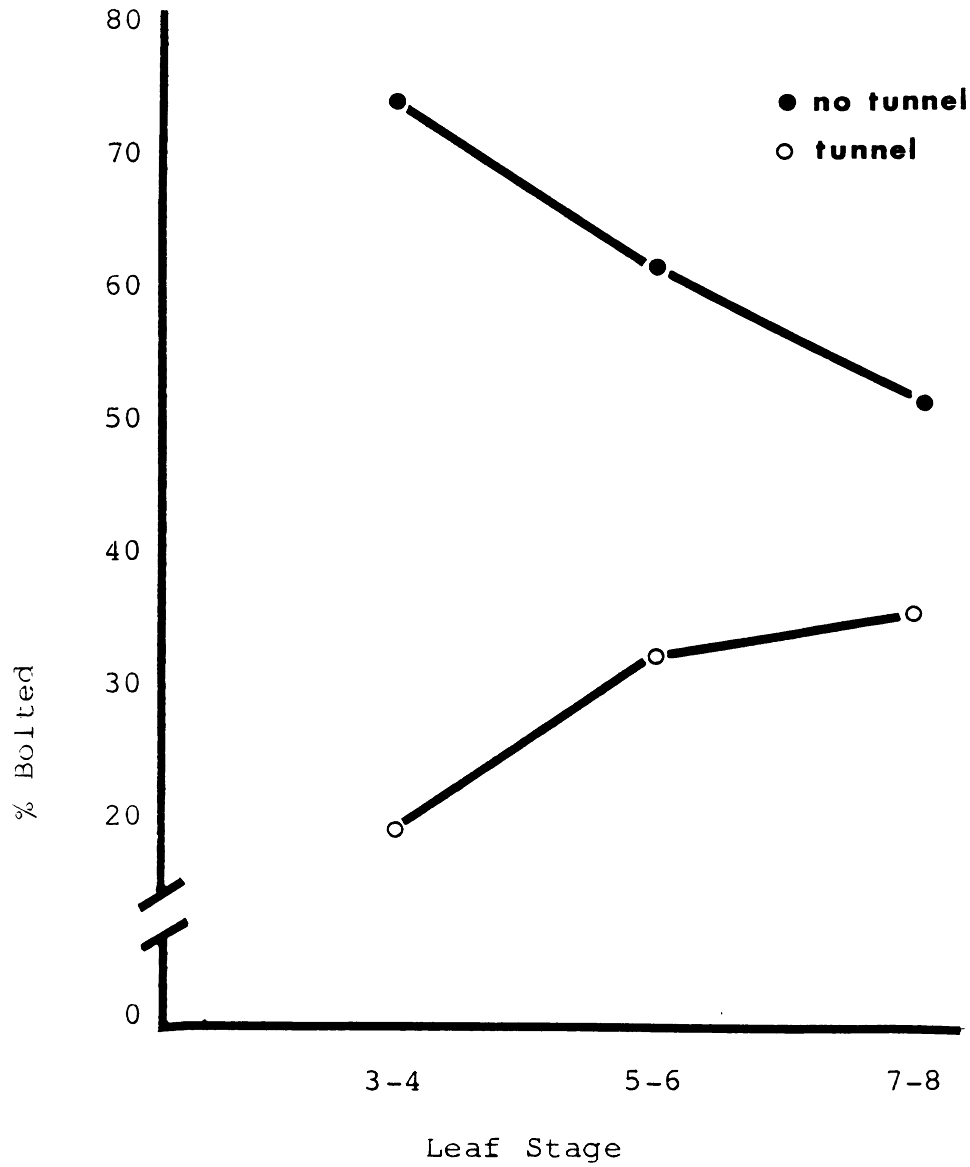


FIGURE 3: THE EFFECT OF TRANSPLANT LEAF STAGE AND PROTECTIVE ROW COVERS, ON PERCENT OF BOLTERS IN CHINESE CABBAGE (CV. NAGAOKA #2), HRC, 1981.

TABLE 4: EFFECTS OF TRANSPLANT LEAF STAGE, DEGREE OF DEFOLIATION, AND PROTECTIVE COVERS, ON QUALITY AND YIELD OF CHINESE CABBAGE, (CV. NAGAOKA #2), HRC, 1981

Parameter	Leaf Stage				% Defoliation				Cover		
	3-4	5-6	7-8	LSD	0	25	50	LSD	Yes	No	LSD
Head Diameter (cm)	14.1	15.1	14.1	n.s.	14.1	14.3	15.0	n.s.	13.9	14.9	n.s.
Head Length (cm)	21.3	21.4	21.2	n.s.	21.0	21.1	21.8	n.s.	21.3	21.3	n.s.
Head Weight (kgms)	1.26	1.42	1.24	n.s.	1.27	1.23	1.43	n.s.	1.26	1.36	n.s.
Internal Stalk (cm)	17.6	17.5	17.8	n.s.	17.4	17.4	18.1	n.s.	16.7	18.6	1.8*
Percent Bolted	47.6	46.5	41.7	n.s.	50.7	40.1	45.1	n.s.	28.1	62.4	n.s.
Percent Harvested	39.0	47.3	52.7	12.0*	42.1	45.4	51.5	n.s.	57.3	35.7	n.s.

n.s. - not significant at the 10% level

* - significant at the 10% level.

TABLE 5: EFFECTS OF TRANSPLANT LEAF STAGE, DEGREE OF DEFOLIATION, AND PROTECTIVE COVERS, ON QUALITY AND YIELD OF CHINESE CABBAGE, (CV. JADE PAGODA), HRC, 1981

Parameter	Leaf Stage				% Defoliation				Cover		
	3-4	5-6	7-8	LSD	0	25	50	LSD	Yes	No	LSD
Head Diameter (cm)	13.4	12.6	12.6	n.s.	12.7	12.7	13.0	n.s.	12.5	13.4	n.s.
Head Length (cm)	31.1	29.6	31.4	n.s.	31.2	30.4	30.5	n.s.	30.2	31.5	n.s.
Head Weight (kgms)	1.61	1.38	1.50	n.s.	1.52	1.44	1.51	n.s.	1.39	1.65	n.s.
Internal Stalk (cm)	23.1	21.8	24.6	n.s.	23.8	23.6	22.4	n.s.	21.6	26.0	n.s.
Percent Bolted	63.6	56.4	67.8	n.s.	59.9	66.6	61.2	n.s.	48.6	76.6	20.2**
Percent Harvested	16.3	22.8	22.9	n.s.	26.4	14.4	21.1	9.5**	28.7	12.6	11.6*

n.s. - not significant at the 10% level

* - significant at the 10% level

** - significant at the 5% level

harvested was also effected by the degree of defoliation. Unpruned plants produced more harvestable plants than those slightly (25%) pruned (P = .05) (Table 5). There were no significant differences in percentage of harvestable plants between slightly (25%) and severely (50%) pruned plants or unpruned and severely (50%) pruned plants.

Muck Farm, Nagaoka #2, Spring 1981

Harvesting began on 7/8 and continued until 7/12. Head diameter was effected by the second order interaction, leaf stage X pruning X tunnel. Trend analysis suggested that only the head diameter of the unprotected plants were effected by the interaction: (1) a quadratic trend at the 3-4 leaf stage with increased pruning in which the slightly (25%) pruned plants produced heads largest in diameter (P = .01), (2) a significant linear relationship at the 5-6 leaf stage which showed a decrease in head diameter with increased pruning (P = .05), and (3) a linear trend at the 7-8 leaf stage which showed an increase in head diameter with increased pruning (P = .005) (Figure 4).

Head length was also effected by the second order interaction (leaf stage X pruning X tunnel). Trend analysis showed that only the unprotected plants were effected by the interaction: (1) a linear-quadratic relationship at the 3-4 leaf stage in which the slightly (25%) pruned plants produced

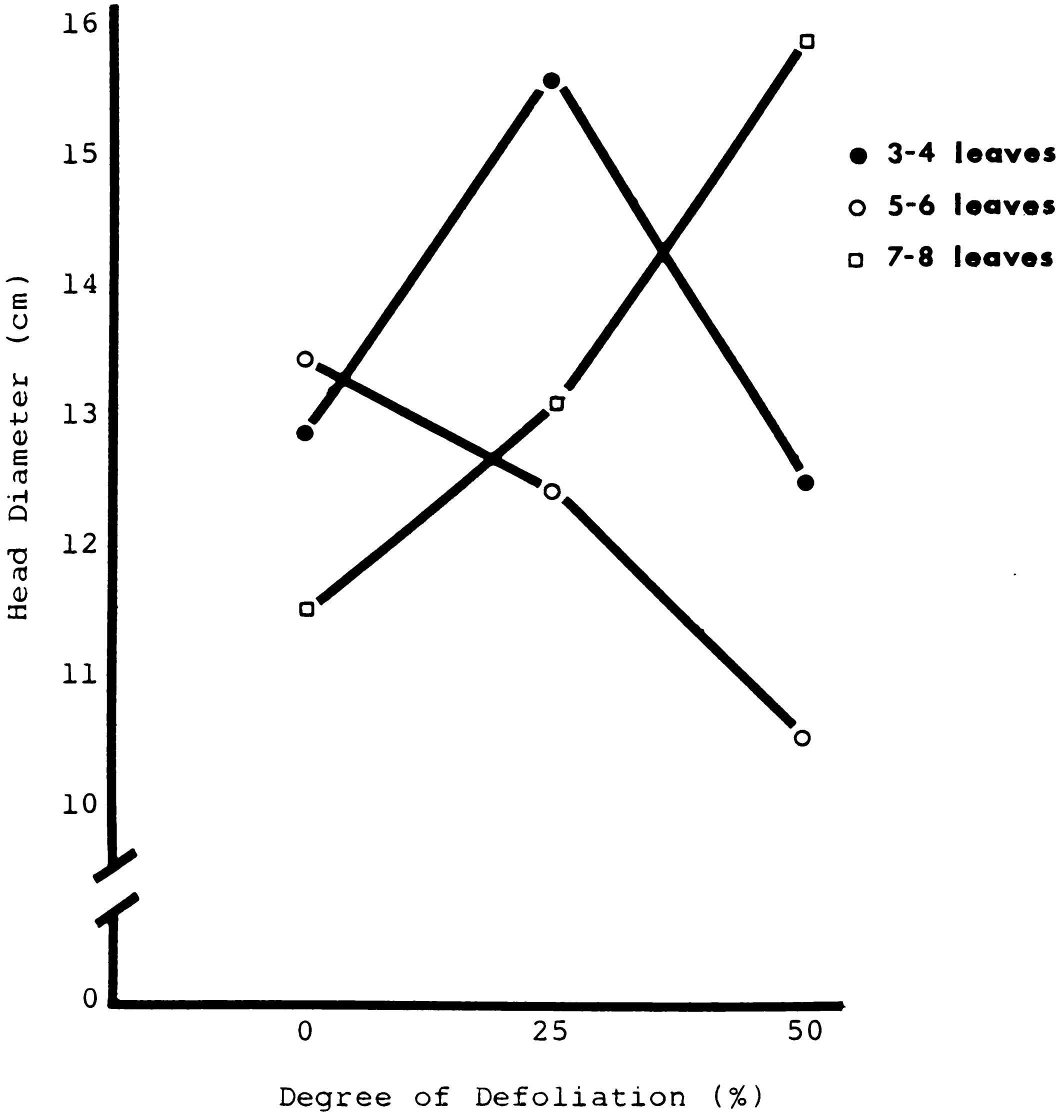


FIGURE 4: THE EFFECT OF DEGREE OF DEFOLIATION AND TRANSPLANT LEAF STAGE, ON HEAD DIAMETER OF CHINESE CABBAGE GROWN UNPROTECTED (CV. NAGAOKA #2), MUCK FARM, 1981

the longest heads (P = .025- .01), (2) a linear trend at the 5-6 leaf stage which showed a decrease in head length with increased pruning (P = .005), and (3) a linear trend at the 7-8 leaf stage which showed an increase in head length when plants were more severely (50%) pruned (P = .01) (Figure 5).

Head weight was effected by the leaf stage X pruning X tunnel interaction. This second order interaction only effected the head weights of unprotected plants: (1) a quadratic relationship at the 3-4 leaf stage with increased pruning; the slightly (25%) pruned plants having produced the largest head weights (P = .005), (2) a negative linear trend at the 5-6 leaf stage with increased pruning (P = .05), and (3) a positive linear trend of head weight at the 7-8 leaf stage as pruning increased (P = .025) (Figure 6).

The internal flower stalk length was significantly effected by the use of the protective tunnels. The protected plants had shorter internal stalks than unprotected plants (P - .05) (Table 6). The leaf stage X pruning X tunnel interaction also had a significant effect on internal stalk development. Trend analysis suggested that in the unprotected plants, with increased pruning: (1) the 3-4 leaf stage showed a linear-quadratic relationship in which the slightly (25%) pruned transplants developed the longest internal stalks (P - .05- .001), (2) the 5-6 leaf stage showed negative linear relationship (P = .025), and (3) the 7-8 leaf stage

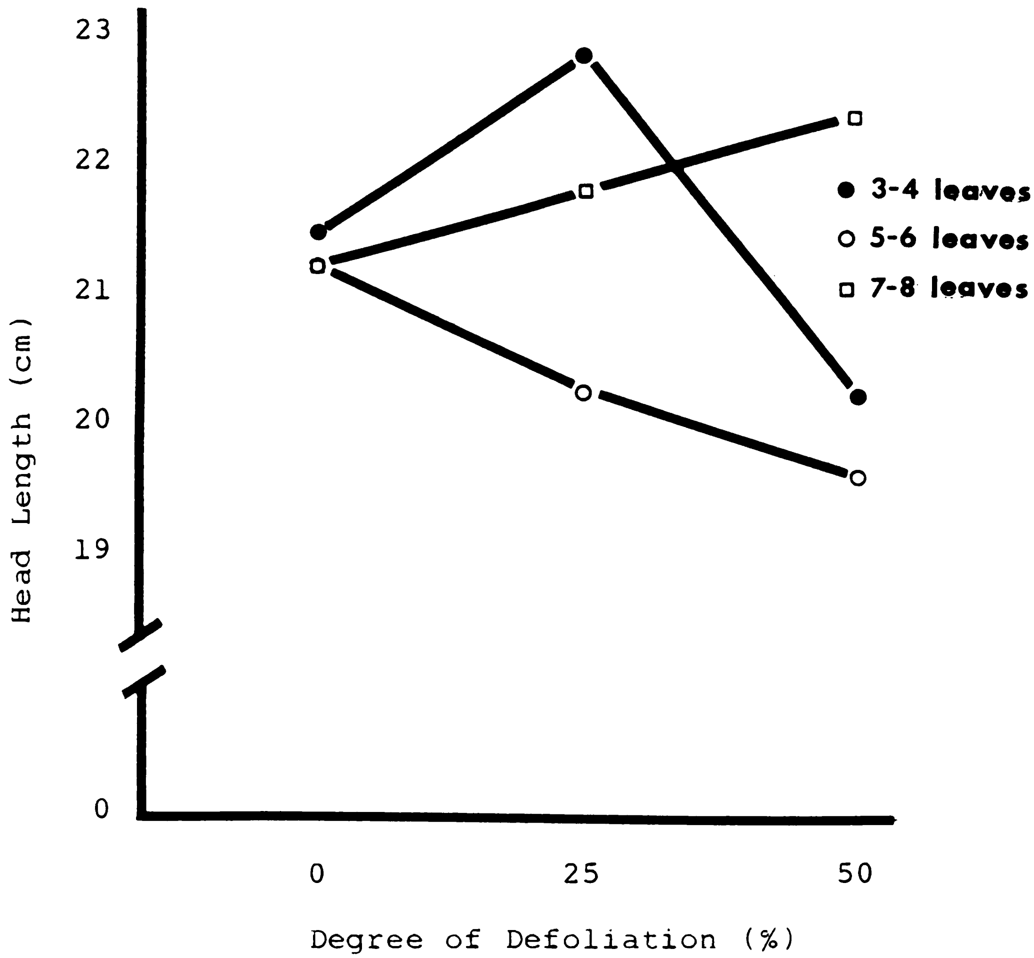


FIGURE 5: THE EFFECT OF DEGREE OF DEFOLIATION AND TRANSPLANT LEAF STAGE, ON HEAD LENGTH OF CHINESE CABBAGE GROWN UNPROTECTED (CV. NAGAOKA #2), MUCK FARM, 1981

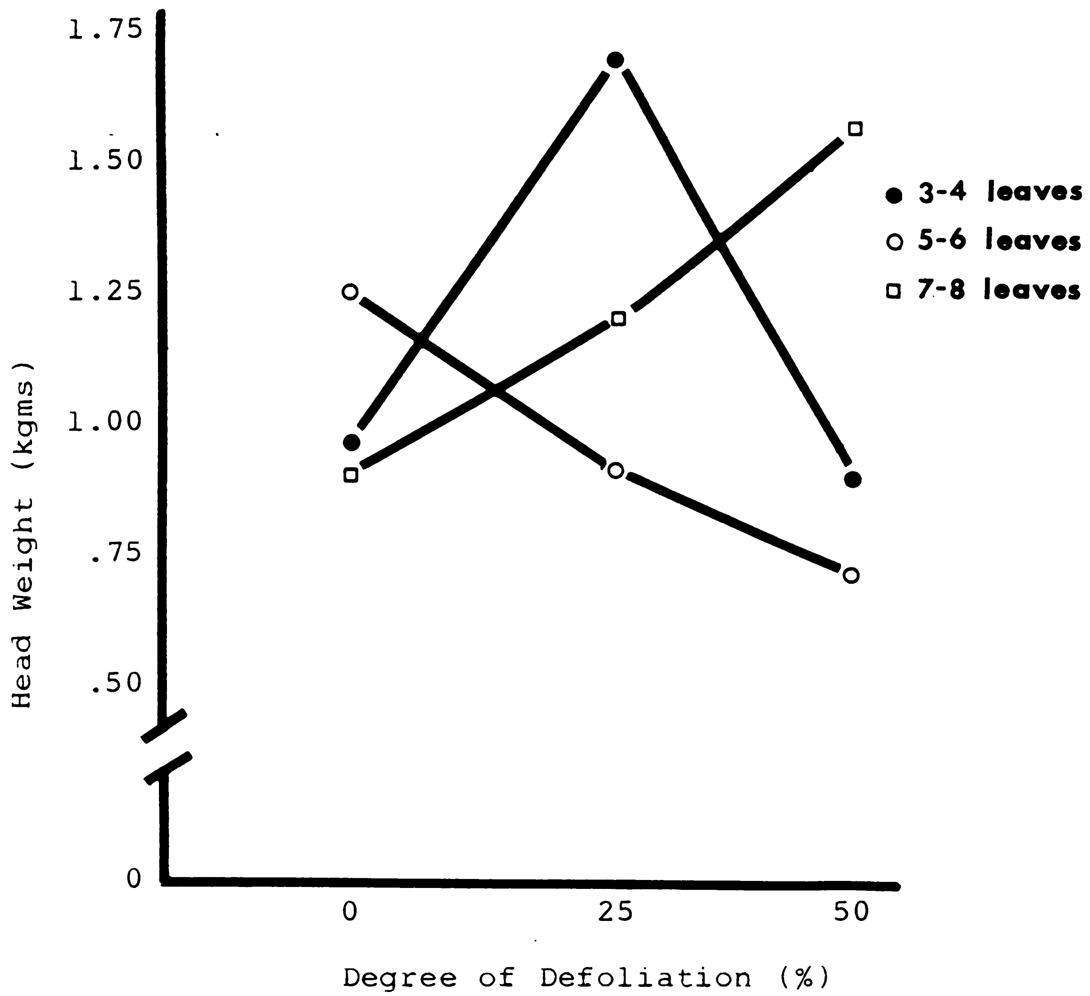


FIGURE 6: THE EFFECT OF DEGREE OF DEFOLIATION AND TRANSPLANT LEAF STAGE, ON HEAD WEIGHT OF CHINESE CABBAGE GROWN UNPROTECTED (CV. NAGAOKA #2), MUCK FARM, 1981

TABLE 6: EFFECTS OF TRANSPLANT LEAF STAGE, DEGREE OF DEFOLIATION, AND PROTECTIVE COVERS, ON QUALITY AND YIELD OF CHINESE CABBAGE, (CV. NAGAOKA #2), MUCK FARM, 1981

Parameter	Leaf Stage				% Defoliation				Cover		
	3-4	5-6	7-8	LSD	0	25	50	LSD	Yes	No	LSD
Head Diameter (cm)	13.4	12.8	13.9	n.s.	13.4	13.7	13.0	n.s.	13.6	13.1	n.s.
Head Length (cm)	21.5	20.3	21.9	n.s.	21.4	21.6	20.7	n.s.	21.1	21.4	n.s.
Head Weight (kgms)	1.19	1.07	1.31	n.s.	1.20	1.27	1.11	n.s.	1.27	1.12	n.s.
Internal Stalk (cm)	16.9	15.9	18.2	n.s.	17.0	17.5	16.5	n.s.	15.2	18.8	3.1*
Percent Bolted	45.1	37.6	48.1	n.s.	47.1	44.6	39.2	n.s.	18.1	69.1	32.9*
Percent Harvested	52.3	61.8	50.8	n.s.	51.8	53.4	59.7	n.s.	80.3	29.7	50.5*

n.s. - not significant at the 10% level

* - significant at the 5% level

showed a positive linear trend in stalk length with increased pruning (P = .025) (Figure 7). The use of protective tunnel reduced the number of bolters and resulted in a greater total percentage of heads harvested than when unprotected (P = .05) (Table 6).

Muck Farm, Jade Pagoda, Spring 1981

Harvesting commenced on 7/15 and continued until 7/17. Mean head diameter comparisons between leaf stages showed that the 7-8 leaf transplants significantly produced heads larger in diameter than the 3-4 leaf stage plants (P = .05) (Table 7). Head differences were not significant between the 3-4 and 5-6 or 5-6 and 7-8 leaf stages.

Although main treatment effects (leaf stage, pruning, tunnel) did not effect head length, the second order interaction, leaf stage X pruning X tunnel had a significant effect on head length of unprotected plants. A negative linear trend in head length was noted with increased pruning at the 5-6 leaf stage (P = .005). At the 7-8 leaf stage, a quadratic relationship was noted in which the slightly (25%) pruned plants produced the longest heads (P = .025) (Figure 8).

Head weight of Jade Pagoda grown without cover was greater than when grown protected for all treatments (P = .05) (Table 7).

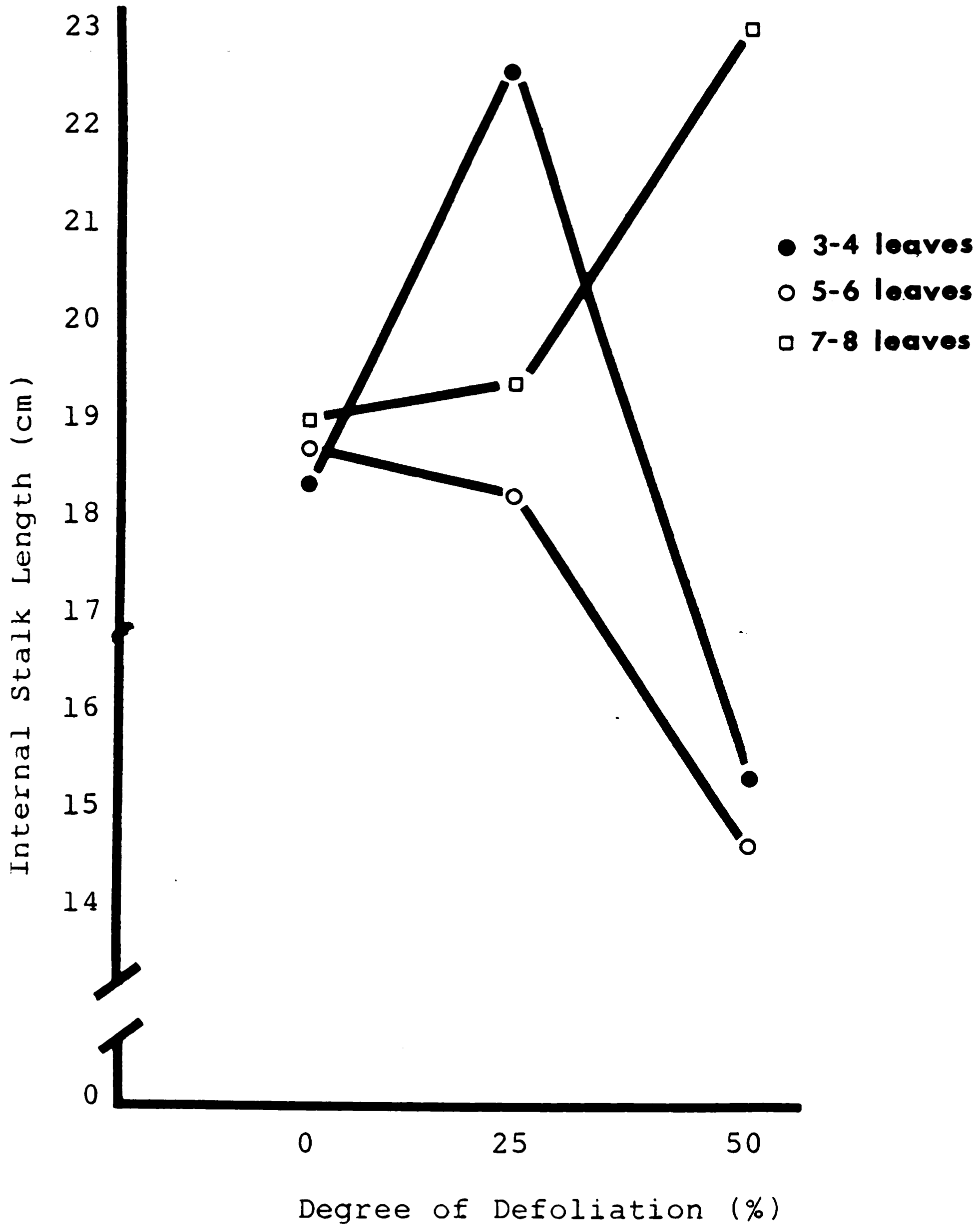


FIGURE 7: THE EFFECT OF DEGREE OF DEFOLIATION AND TRANSPLANT LEAF STAGE, ON INTERNAL STALK LENGTH OF CHINESE CABBAGE GROWN UNPROTECTED (CV. NAGAOKA #2), MUCK FARM, 1981.

TABLE 7: EFFECTS OF TRANSPLANT LEAF STAGE, DEGREE OF DEFOLIATION, AND PROTECTIVE COVERS, ON QUALITY AND YIELD OF CHINESE CABBAGE, (CV. JADE PAGODA), MUCK FARM, 1981

Parameter	Leaf Stage				% Defoliation				Cover		
	3-4	5-6	7-8	LSD	0	25	50	LSD	Yes	No	LSD
Head Diameter (cm)	10.4	11.1	11.9	1.2**	11.3	10.9	11.2	n.s.	10.8	11.5	n.s.
Head Length (cm)	32.4	32.5	32.7	n.s	32.6	32.8	32.3	n.s.	31.9	33.2	n.s.
Head Weight (kgms)	1.16	1.35	1.51	n.s.	1.40	1.37	1.26	n.s.	1.14	1.54	.26**
Internal Stalk (cm)	27.4	25.9	25.7	n.s.	26.6	27.2	25.2	n.s.	23.7	29.0	3.9***
Percent Bolted	37.6	36.3	36.1	n.s.	35.9	36.0	38.1	n.s.	10.2	63.1	48.5***
Percent Harvested	30.9	31.3	38.8	n.s.	32.4	37.9	30.7	n.s.	40.4	27.0	9.3*

n.s. - not significant at 10% level
* - significant at the 10% level
** - significant at the 5% level
*** - significant at the 2.5% level

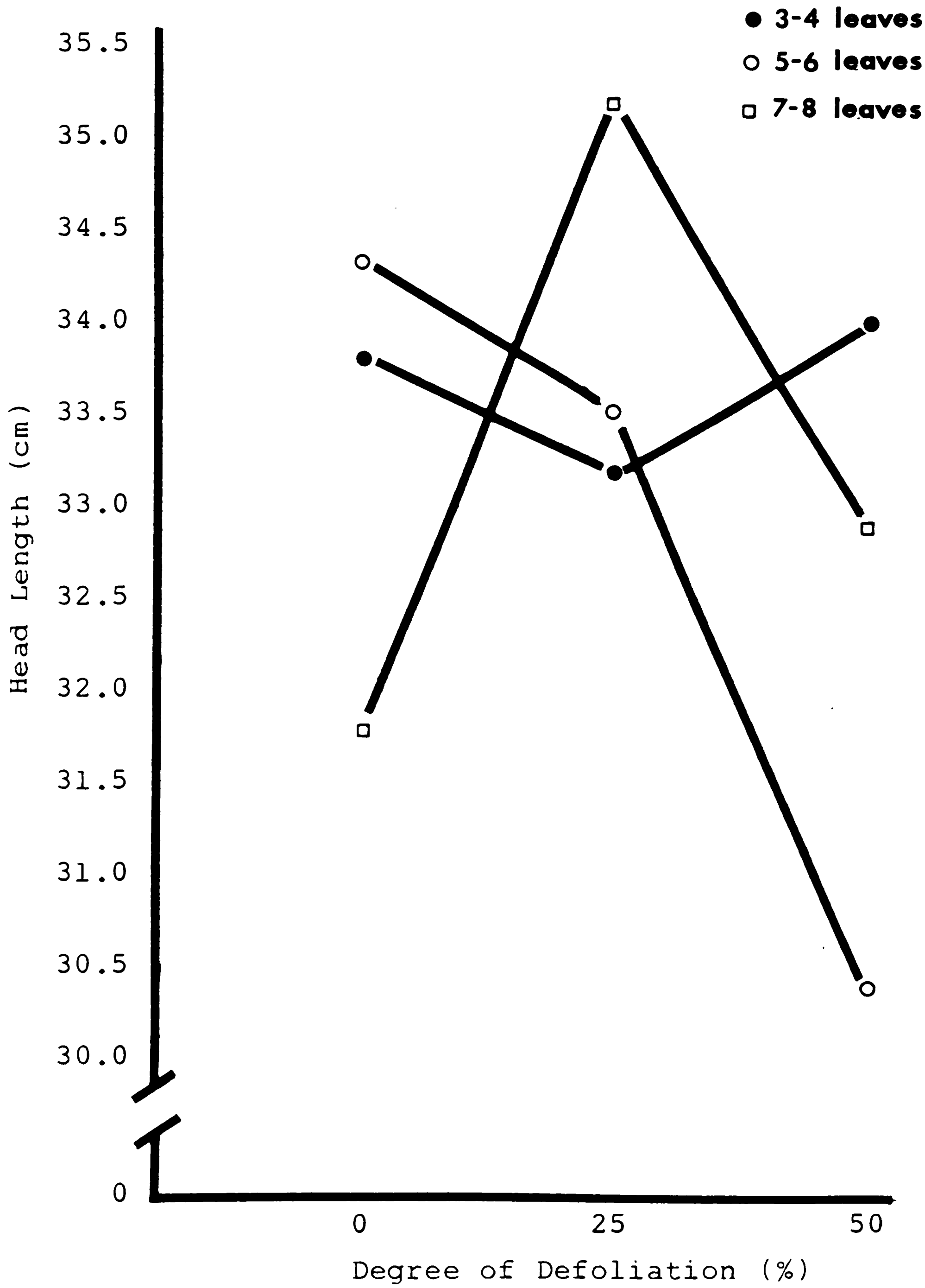


FIGURE 8: THE EFFECT OF DEGREE OF DEFOLIATION AND TRANSPLANT LEAF STAGE, ON HEAD LENGTH OF CHINESE CABBAGE GROWN UNPROTECTED (CV. JADE PAGODA), MUCK FARM, 1981

It was also determined that the leaf stage X pruning X tunnel interaction effected head weight. Trend analysis suggested that when plants grown under the tunnels, the larger transplants (7-8 leaves) showed a negative linear relationship in head weight with increased pruning (P = .05) (Figure 9). Trend analysis also suggested that with the unprotected plants, the 7-8 leaf stage plants showed a quadratic trend with increased pruning with the slightly (25%) pruned plants producing the heaviest heads (P = .10). The 5-6 leaf stage plants showed a negative linear relationship of head weight with increased pruning (P = .025) (Figure 10).

Internal stalk development and the percentage of plants showing visible flower stalks (bolters) were significantly inhibited by the use of the protective tunnel (P = .025) (Table 7). Since fewer bolters were found in the protected plants, significantly more heads were harvested from the protected plants than from unprotected plants (P = .10) (Table 7).

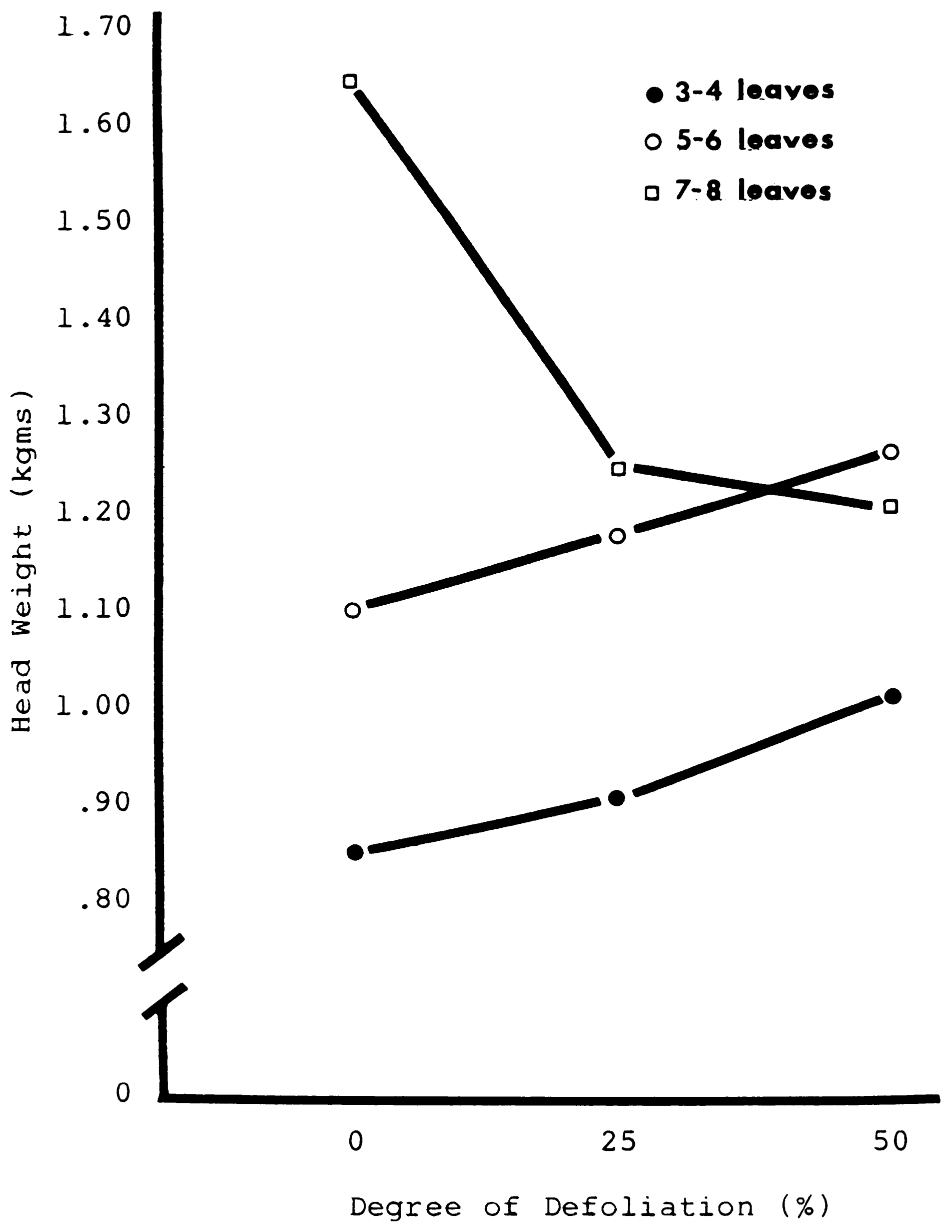


FIGURE 9: THE EFFECT OF DEGREE OF DEFOLIATION AND TRANSPLANT LEAF STAGE, ON HEAD WEIGHT OF CHINESE CABBAGE GROWN UNDER TUNNELS (CV. JADE PAGODA), MUCK FARM, 1981

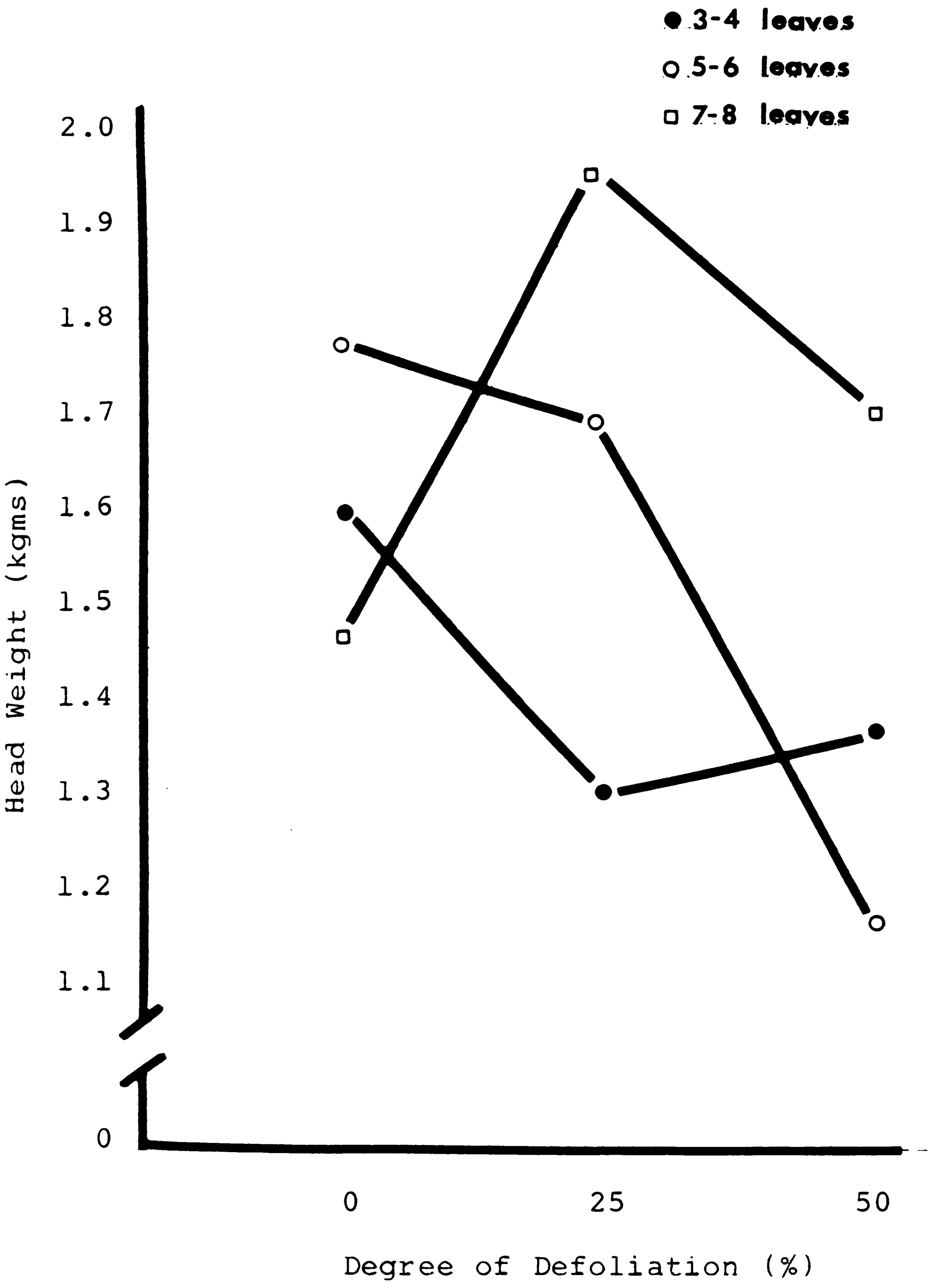


FIGURE 10: THE EFFECT OF DEGREE OF DEFOLIATION AND TRANSPLANT LEAF STAGE, ON HEAD WEIGHT OF CHINESE CABBAGE GROWN UNPROTECTED (CV. JADE PAGODA), MUCK FARM, 1981

GENERAL CONCLUSIONS

1. The use of the protective tunnels significantly reduced the number of bolters and the length of internal flower stalk.

2. Older seedlings (5-6 and 7-8 leaf stages) produce a greater percentage of harvestable heads than the smaller seedlings (3-4 leaves).

3. The protective tunnels hasten early plant growth, however, subsequent growth after tunnel removal was slowed down.

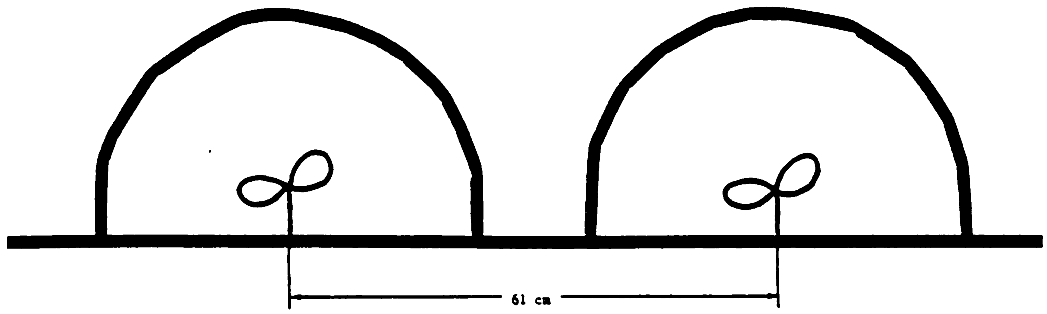
4. There appeared to be more uniform growth between treatments when plants were grown under the tunnels.

5. Pruning decreased early plant growth, however, harvested head weight was not significantly effected.

6. It appeared that the 5-6 leaf transplants left unpruned and grown protected produced the best overall yield and quality.

APPENDIX

FIGURE A-1: DIAGRAM OF THE CHINESE CABBAGE SEEDLING TUNNEL SYSTEM USED IN JAPAN (BELOW) AND THE SYSTEM USED IN MICHIGAN (ABOVE).


61 cm

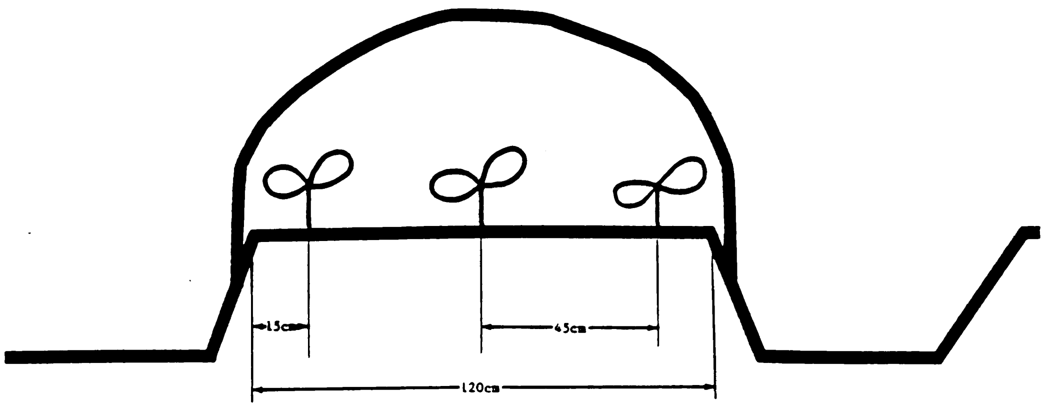

15cm
45cm
120cm

FIGURE A-2: MEAN AIR AND SOIL TEMPERATURES WITHIN AND OUTSIDE THE TUNNEL SYSTEM FROM 5/6 TO 5/11/80

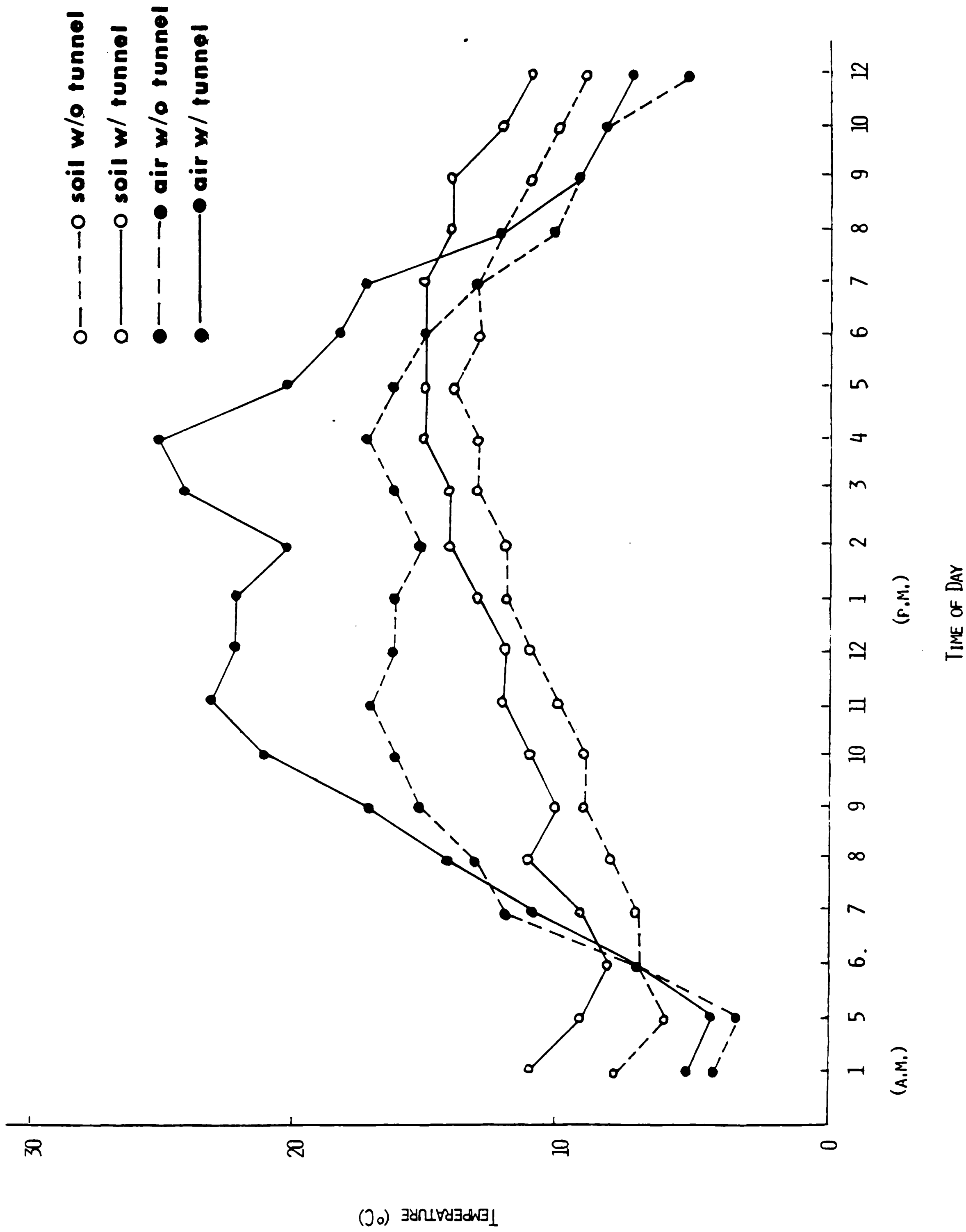

soil w/o tunnel
soil w/ tunnel
air w/o tunnel
air w/ tunnel
TEMPERATURE (°C)
0
10
20
30
1
5
6
7
8
9
10
11
12
1
2
3
4
5
6
7
8
9
10
12
(A.M.)
(P.M.)
TIME OF DAY

FIGURE A-3: MEAN AIR AND SOIL TEMPERATURES WITHIN AND OUTSIDE THE TUNNEL SYSTEM FROM 5/11 TO 5/16/80

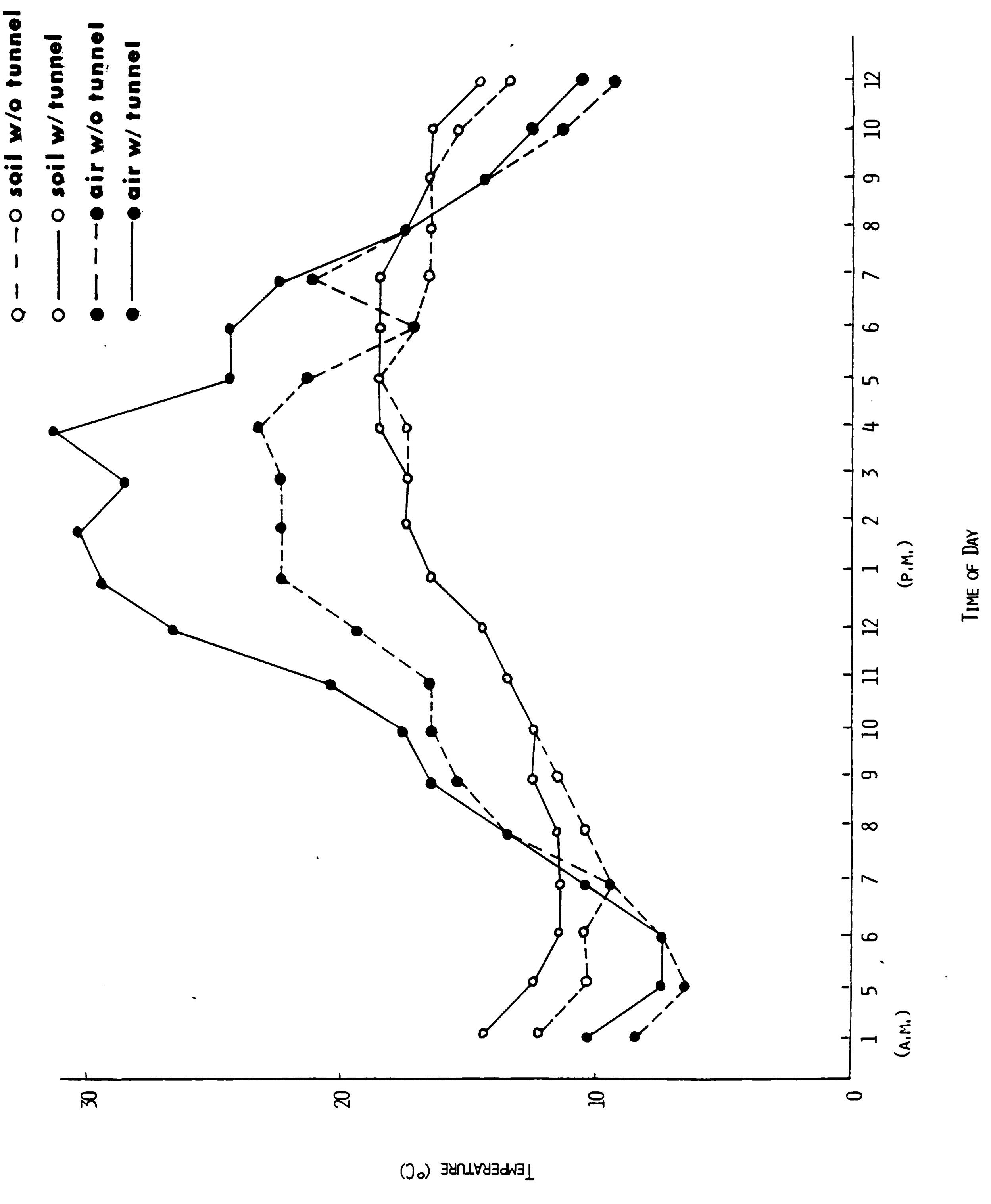
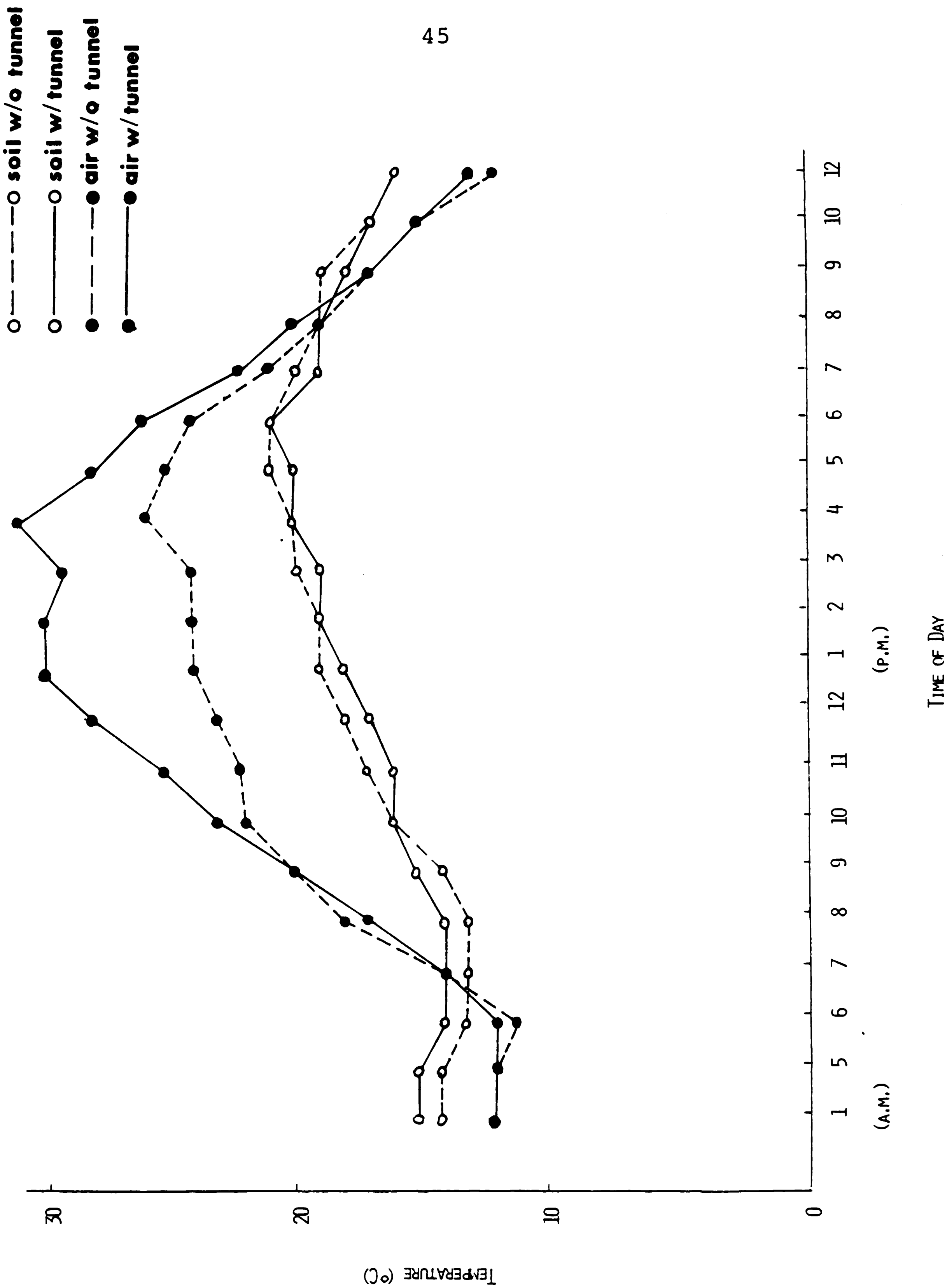

soil w/o tunnel
soil w/ tunnel
air w/o tunnel
air w/ tunnel
TEMPERATURE (°C)
TIME OF DAY
(A.M.)
(P.M.)

FIGURE A-4: MEAN AIR AND SOIL TEMPERATURES WITHIN AND OUTSIDE THE TUNNEL SYSTEM FROM 5/16 TO 5/21/80



soil w/o tunnel
soil w/ tunnel
air w/o tunnel
air w/tunnel
Temperature (°C)
0
10
20
30
(A.M.)
1 5 6 7 8 9 10 11 12
(P.M.)
1 2 3 4 5 6 7 8 9 10 12
Time of Day

TABLE A-1: MAXIMUM/MINIMUM AIR AND SOIL TEMPERATURES WITHIN AND OUTSIDE THE TUNNEL SYSTEM, 1981

Muck Farm

5/1-5/5		5/6-5/10		5/19-5/23		5/24-5/27		
Air	Soil	Air	Soil	Air	Soil	Air	Soil	
31/6	19/11	25/2	15/8	32/5	22/11	28/13	22/16	(inside tunnel)
22/6	11/8	16/1	10/5	24/3	15/9	21/13	17/14	(outside tunnel)

Hort Farm

4/28-5/2		5/3-5/7		5/8-5/12		5/13-5/17		5/18-5/22		5/23-5/26		
Air	Soil	Air	Soil	Air	Soil	Air	Soil	Air	Soil	Air	Soil	
24/5	18/8	29/5	20/9	19/3	15/7	25/5	17/7	29/3	21/8	25/13	24/15	(inside tunnel)
15/5	12/7	18/6	12/8	13/4	10/6	16/5	12/7	22/4	16/7	23/14	18/13	(outside tunnel)

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