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The Influence of Cold Storage on the Survival and Flowering of Field Planted Cabbage, Carrot and Beet in Sri Lanka

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Abstract : An investigation was conducted to determine the influence of the storage of cabbage, carrot and beet plants at low temperatures (0.5 to 1.0°C and 7.0 to 8.5°C) for different durations (15 days to 60 days) on their flowering when they were subsequently planted in the field at two locations in Sri Lanka having different elevations (Kundasale, 450 m and Nuwara Eliya, 1,850 m).

The results indicate that all the cabbage plants that were pre-stored at 0.5 to 1.0°C for 40 days flowered when they were planted at Nuwara Eliya. Only a maximum of 57.14% flowered at Kundasale. Carrots stored at the same temperature for 50 days gave the best response (18% flowering) when grown at Kundasale. The survival of the plants at a location was associated with the incidence of rainfall after field planting. The lower mean temperature at Nuwara Eliya promoted flowering and the development of the normal inflorescences in cabbage while it suppressed flowering in carrot. The higher mean temperature at Kundasale promoted flowering in carrots and partially inhibited flowering in cabbage and suppressed the development of normal inflorescences. Beet did not respond to the treatments.

1. Introduction

Biennial, exotic vegetables like cabbage, *Brassica oleracea var. capitata* L., carrot, *Daucus carota var. sativa* L., and beet, *Beta vulgaris* L., are grown in several parts of Sri Lanka under different agroclimatic conditions. Their cultivation is concentrated predominantly in the highlands at elevations ranging from 750 to 1,900 m. At these elevations vegetative growth is normal, and fresh market vegetables true to type are obtained throughout the year. However, even during the coolest months of the year, field temperatures are not low enough to induce natural flowering. Consequently, the seed requirement for commercial cultivations has to be imported annually, utilizing scarce foreign exchange. If the seed could be produced locally, besides conserving foreign exchange, a new form of agricultural employment could be developed by diversifying the use of some land for the production of seed of exotic vegetables.

A pre-requisite for seed production in these vegetables is flowering. Miller[3] has[8] reported that cabbage heads flower if they were pre-stored at 4.4°C for 30 to 60 days and then planted in the field. Carrots when pre-stored at 4.4 to 10.0°C for 15 to 60 days were shown to flower by Sakr and Thompson.[4] Beets were found to require higher storage temperatures ranging from 8 to 18°C for 2 to 3 months.[1,2,6,7] The experiments reported here were attempted to examine whether exotic vegetables would flower under field conditions in Sri Lanka when they were planted after they had been pre-stored in cold temperatures.

2. Materials and Methods

2.1. Experiment I

The experiment was conducted at the University Farm, Kundasale (elevation 450 m) from 24 December 1970 to 31 May 1971.

2.1.1. *Treatment of the plants for cold storage*

Beet : Whole plants of the cultivar Detroit Red were uprooted on 23 December 1970 keeping much of the root tip intact. The outer leaves were removed at the base of the petioles, leaving the small apical leaves and the apical bud intact. The plants so prepared were dipped in a solution of cupravit (50 % copper oxychloride), at a dilution of 1 gm in 2.5 litres of water and air dried.

Cabbage : Plants of the cultivar KY cross were uprooted with their roots intact on 23 December 1970. After removing their outer leaves, the plants were dipped in the solution of cupravit, as for beet, and air-dried.

Carrot : Whole plants of the cultivar Cape Market were obtained from the wholesale market in Kandy. They were prepared for cold storage as for beet.

2.1.2. *Cold storage*

One lot of treated plants of beet, cabbage and carrot was packed in wooden crates lined with white polythene and stored in a cold room at a temperature of 0.5 to 1.0°C. Another lot of beet and carrot was packed in sealed white polythene bags and stored in a refrigerator at a temperature of 7.0 to 8.5°C. Sub-lots of the plants were removed from cold storage for field planting at intervals of 15 days, 30 days and 60 days.

2.1.3 *Field planting*

The three kinds of vegetables were planted in separate blocks in the same field. Each plot of cabbage had 10 plants replicated 3 times. Each plot of beet and carrot had 10 plants replicated 4 times. Planting was done the day they were removed from storage.

Cabbage was spaced 60 cm in the row and 90 cm between rows. Beet and carrot were spaced 15 cm in the row and 60 cm between rows. One week after the cabbage was planted, a cross shaped incision 2.5 cm deep was made in the head.

Recommended practices were adopted for pest and disease control and fertilization.[5] The plots were hand watered regularly.

2.2. Experiment II

This experiment was conducted with cabbage and carrot from 13 November 1971 to 15 April 1972 at the University Farm, Kundasale and the Government Research Station, Nuwara Eliya (elevation 1,850 m). Plants were stored for 40 days, 50 days

and 60 days at 0.5 to 1.5°C in a cold room. The method of pre-treatment and field planting was identical to experiment I. Plants of each treatment were removed from cold storage and one lot was planted in Kundasale the same day, while the other lot was planted in Nuwara Eliya the next day.

3. Results

3.1. Experiment I

The proportion of cold stored plants which survived and flowered after transplanting in the field is indicated in Table 1.

3.1.1. *Cabbage*

All the plants that were stored for 15 days and 60 days at 0.5 to 1.0°C survived in the field for 30 days. After that, the plants of the 15-day treatment showed a loss of 20% plants, whereas the 60-day treatment did not record a loss. Plant survival in the 30-day storage treatment was 46.66% ; this was maintained until the end of the trial.

Flowering was observed only in the 60-day treatment. Two plants flowered, one in 19 days and the other in 22 days after planting, to form small and poorly differentiated inflorescences.

3.1.2. *Beet*

Plant survival was highest among those stored for 15 days at 0.5 to 1.0°C. At this storage temperature, plant survival decreased when the period of storage was lengthened. All the plants which grew and survived for 30 days continued to do so until the end of the 90-day trial period.

The plants that were stored at 7.0 to 8.5°C for 15 days and 60 days showed a lesser survival ability when compared to those stored at the lower temperature regime. Plant mortality in the 60-day storage treatment was particularly high and only 17.5% survived the first month.

Flowering was not noticed in any of the treatments.

3.1.3. *Carrot*

Only 3.30% of the plants stored for 15 and 30 days at 0.5 to 1.0°C survived the first month after transplanting. None of the plants of the other treatments survived the first month. One plant of the 30-day low temperature treatment flowered in 43 days after planting.

3.1.4. *Rainfall*

Table 2 gives the total rainfall and its distribution from 1 January 1971 up to the end of March 1971. Rainfall was high during the weeks when the 15-day and 60-day treatments were planted on 8 January and 27 February respectively. Rainfall was low during the week the 30-day treatment was planted (23 January 1971) and it was followed by a dry spell of 3 weeks.

TABLE 1. Influence of cold storage of cabbage, beet and carrot on the survival and flowering of field grown plants.

	Storage temperature (°C)	Days in storage	Planting date 1971	%Survival — Mean of replicates			Plants flowering		Days to flower
				30 days	60 days	90 days	No.	%	
Cabbage	0.5 — 1.0	15	8 Jan.	100	80	80	0		
		30	23 Jan.	46.66	46.66	46.66	0		
		60	27 Feb.	100	100	100	2	6.22	19—22
Beet	0.5 — 1.0	15	8 Jan.	65	65	65	0		
		30	23 Jan.	60	60	60	0		
		60	27 Feb.	50	50	50	0		
	7.0 — 8.5	15	8 Jan.	42.5	42.5	42.5	0		
		30	23 Jan.	55	55	55	0		
		60	27 Feb.	17.5	17.5	17.5	0		
Carrot	0.5 — 1.0	15	8 Jan.	3.3	0	0	0		
		30	23 Jan.	3.3	0	0	1	1.66	43
		60*	27 Feb.	0	0	0	0		
	7.0 — 8.5	15*	8 Jan.	0	0	0	0		
		30**	23 Jan.	0	0	0	0		
		60***							

* Rotting in storage left only 10 plants per replicate for field planting.
** Rotting in storage left only 7 plants per replicate for field planting.
*** All the plants rotted in storage.

TABLE 2. Amount of rainfall and its distribution at Kundasale and Nuwara Eliya.

Week 1971	Rainfall	
	Total (mm)	No. of days
Jan. 1 — Jan. 7	3.2	4
Jan. 8 — Jan. 14	4.8	3
Jan. 15 — Jan. 21	—	—
Jan. 22 — Jan. 28	0.3	1
Jan. 29 — Feb. 4	—	—
Feb. 5 — Feb. 11	—	—
Feb. 12 — Feb. 18	—	—
Feb. 19 — Feb. 25	7.4	2
Feb. 26 — Mar. 4	9.5	3
Mar. 5 — Mar. 11	2.3	3
Mar. 12 — Mar. 18	—	—
Mar. 19 — Mar. 25	—	—

3.2. Experiment II

3.2.1. *Plant survival*

Cabbage plants that were cold-stored for 60 days survived better at both locations during the entire experimental period when compared with the other two storage treatments (Table 3). The best survival was recorded among plants that were stored for 60 days and then field planted at Nuwara Eliya. The rate of loss of field plants was highest during the first 30 days in all treatments at both locations. After 30 days, the rate of loss of plants was in general lower in Nuwara Eliya.

In general, carrot survived better than cabbage at both locations when they were pre-stored at the same temperature for comparable durations of storage (Table 4). As in cabbage, the rate of loss was high during the first 30 days ; but the losses were lower in carrot. With the exception of the 40-day storage treatment, the rate of loss of field plants after 30 days was lower in Nuwara Eliya.

3.2.2. *Flowering*

Cabbage plants of all three storage treatments flowered at both locations (Table 5). All the plants that survived in Nuwara Eliya flowered to give normal, well grown inflorescences. The flowering response at Kundasale was lower in all the treatments and the best response (57.14%) was recorded for the 40-day storage treatment. The inflorescences so formed were poorly developed. Although the average number of days to flower was different for the 40-day, 50-day and 60-day treatments, in general, all healthy plants completed flowering within 7 weeks.

TABLE 3. Influence of cold storage and location of the planting on the survival of field planted cabbage.

Days in cold storage (0.5 — 1.5°C)	Location of planting	Planting date 1971/72	% Survival—Mean of replicates			% Rate of plant mortality		
			30 days	60 days	90 days	1—30 days	31—60 days	61—90 days
40	Kundasale	22 Dec.	46.66	33.33	6.66	53.34	13.33	26.67
40	Nuwara Eliya	23 Dec.	50	33.33	33.33	50	16.67	0
50	Kundasale	3 Jan.	56.66	23.33	0	43.34	33.33	23.33
50	Nuwara Eliya	4 Jan.	50	46.66	46.66	50	3.34	0
60	Kundasale	10 Jan.	66.66	43.33	9.99	33.34	23.33	33.34
60	Nuwara Eliya	11 Jan.	83.33	83.33	83.33	16.67	0	0

TABLE 4. Influence of cold storage and location of the planting on the survival of field planted carrot.

Days in cold storage (0.5 — 1.5°C)	Location of planting	Planting date 1971/72	% Survival—Mean of replicates			% Rate of plant mortality		
			30 days	60 days	90 days	1—30 days	31—60 days	61—90 days
40	Kundasale	22 Dec.	90	70	66.66	10	20	3.34
40	Nuwara Eliya	23 Dec.	83.33	81.66	41.66	16.67	1.67	40
50	Kundasale	3 Jan.	78.33	73.33	65	21.67	5	8.33
50	Nuwara Eliya	4 Jan.	86.66	85	85	13.34	1.66	0
60	Kundasale	10 Jan.	78.33	71.66	31.66	21.67	6.34	40
60	Nuwara Eliya	11 Jan.	81.66	76.66	76.66	18.34	5	0

TABLE 5. Influence of cold storage and location of the planting on the flowering of field planted cabbage and carrot.

Days in cold storage (0.5—1.5°C)	Location of planting	Planting date 1971/72	Cabbage					Carrot				
			Total flowered	% of total treated	% of total surviving	Flowering range (days)	Av. no. days to flower	Total flowered	% of total treated	% of total surviving	Flowering range (days)	Av. no. days to flower
40	Kundasale	22 Dec.	8	26.66	57.14	37-46	41.5	4	6.66	10	32-55	44.5
40	Nuwara Eliya	23 Dec.	10	33.33	100	49-126*	72.1*	0	0	0	—	—
50	Kundasale	3 Jan.	2	6.66	10.53	31	31	7	11.66	18	32-55	40.5
50	Nuwara Eliya	4 Jan.	14	46.66	100	37-52	43	1	1.66	1.92	61	61
60	Kundasale	10 Jan.	4	13.33	22.20	29-44	35.5	5	8.33	11.63	30-54	36
60	Nuwara Eliya	11 Jan.	25	83.33	100	30-49	37.8	1	1.66	2.17	51	51

*Two plants were retarded in growth and they flowered late. Excluding them, the range was 49-72 days and the average days to flower was 59 days.

TABLE 6. Amount of rainfall and its distribution at Kundasale and Nuwara Eliya.

Week 1971/72	Rainfall				Average temperature (oC)			
	Kundasale		Nuwara Eliya		Kundasale		Nuwara Eliya	
	Total (mm)	No. of rainy days	Total (mm)	No. of rainy days	Max.	Min.	Max.	Min.
Dec. 22 — Dec. 28	1.50	1	1.05	3	24.4	19.2	24.0	12.9
Dec. 29 — Jan. 4	0.43	1	0.70	2	29.3	21.1	25.9	12.5
Jan. 5 — Jan. 11	—	—	0.38	1	30.2	18.7	27.3	8.4
Jan. 12 — Jan. 18	—	—	0.28	1	35.8	18.0	28.9	9.5
Jan. 19 — Jan. 25	0.50	1	1.45	2	33.9	20.6	27.3	10.5
Jan. 26 — Feb. 1	2.82	3	6.50	3	34.6	20.6	26.1	10.3
Feb. 2 — Feb. 8	—	—	—	—	36.9	15.3	28.3	7.7
Feb. 9 — Feb. 15	—	—	—	—	37.9	18.1	30.3	8.0
Feb. 16 — Feb. 22	—	—	—	—	37.8	18.9	29.9	8.4
Feb. 23 — Feb. 29	—	—	—	—	36.4	19.5	28.0	9.4
For entire period	5.25	6	10.36	12	33.7	19.0	26.4	9.7
						Mean (26.4)		Mean (18.7)

The flowering response in carrot was better at Kundasale. At this location, all three storage treatments had flowering plants but the proportion of plants that flowered was low. The best response (11.66%) was recorded in the 50-day treatment. At Nuwara Eliya, the 40-day storage treatment did not induce flowering. In each of the 50-day and 60-day treatments, however, one plant flowered. As in cabbage, the plants that flowered did so within 7 weeks.

3.2.3. *Climatic Data*

Rainfall and temperature recordings at Kundasale and Nuwara Eliya from the first planting date (22 December 1971) up to the end of 7 weeks after the last date of planting (19 January 1972) are given in Table 6. Both the amount of rainfall and its distribution were poor in Kundasale when compared with Nuwara Eliya. Kundasale received 5.25 mm on 6 days during this period. Rainfall was recorded during 4 different weeks, while 6 weeks were dry. Nuwara Eliya had 10.36 mm of rain on 12 days during the same period. Rainfall was recorded during 6 different weeks, followed by 4 dry weeks.

The weekly variation of the maximum and minimum temperature within each of the two locations was small. Between locations, Nuwara Eliya, being at a higher elevation, had a lower average maximum and minimum temperature throughout the experimental period (Table 6). The mean temperature at Kundasale and at Nuwara Eliya for the entire period was 26.3°C and 18.6°C respectively.

4. Discussion

The survival of field transplants of exotic vegetables in Sri Lanka after they have been pre-stored at a cold temperature is essential for seed production. In this respect survival during the first 30 days was critical, as the first experiment has shown that almost all the plants that survived the first 30 days, survived until the end of the experimental period of 90 days. For beets, a longer storage period was less desirable. It was more so when the storage temperature was higher and was probably associated with the breakdown of the stored products, because many beets were observed to be less firm at the time of planting when the duration of storage was longer. The second experiment confirmed that the first month was a critical period, because mortality was highest for both cabbage (Table 3) and carrot (Table 4) during this period.

The first experiment suggested that the survival of cabbage at Kundasale was influenced by rainfall. The 15-day and 60-day treatments survived best, because it had rained soon after transplanting (Table 2). The 30-day treatment had a high mortality as it was associated with relatively low rainfall during the week after transplanting which was followed by a dry spell of 4 weeks. Even though the plants were irrigated, the bright, warm and sunny days which are common at Kundasale during a dry spell would not have been suitable for the quick establishment and high survival of new transplants of cabbage that had a large mass of succulent leaf tissue and no functional roots at transplanting.

The first experiment also suggested that the plants should be stored for more than 30 days at a low temperature to induce flowering in cabbage and carrot.

The second experiment was planned to narrow down the duration of cold storage that was necessary to induce flowering in cabbage and carrot and in addition to determine if a location with a lower mean temperature would have an influence on survival and flowering. Nuwara Eliya proved to be a better location for the field survival of cabbage, not only during the critical first month but also subsequent to it. The higher mortality of cabbage at Kundasale may have been due to the lower rainfall and its poor distribution when compared with Nuwara Eliya (Table 6). Perhaps lesser cloudiness and the higher intensity of radiation may have also encouraged the rapid desiccation and deterioration of plants at Kundasale. Although there was no difference in the field survival of carrot during the first month in the two locations, Nuwara Eliya was a better location for longer survival periods. Carrot was a hardier plant than cabbage at both locations. Rainfall would have influenced the better survival of carrot at Nuwara Eliya, as in the case of cabbage, but its effect was less.

A 40-day cold storage was sufficient to induce cabbage to flower. Even though some carrot plants that were stored for the same length of time flowered, a 50-day treatment was more effective (Table 5). Even though the floral primodia could be induced to form, the development of the inflorescence in the field was influenced by the field temperature. The lower temperatures at Nuwara Eliya would have assisted the elongation and development of a normal inflorescence in cabbage. At Kundasale, however, the lower proportion of flowering plants and the poor development of the inflorescences that emerged from the heads of cabbage plants would have been due to the higher mean temperatures. Even in plants which did not show an inflorescence, the induction of the floral primodia would have occurred in storage but the higher field temperature would have suppressed further development, even though the difference in the mean temperatures between the two locations was only 7.7°C. A similar relationship has been observed by Miller.[3] In his trial, cabbage plants that were grown in a 20°C greenhouse did not flower, whereas all the plants that grew in a 12.5°C greenhouse flowered. In carrot, however, the higher field temperature at Kundasale promoted the development of the inflorescence. But the majority of carrot plants did not show a visible inflorescence. Perhaps under field conditions in Sri Lanka, carrot may require a still higher field temperature for the development of its inflorescence. A location in the dry zone lowlands of Sri Lanka would be more suitable.

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