JBP were always larger than EWP seedlings under similar experimental treatments.

In this study caution must be taken when applying results of the predicted height increment plots to other experimental systems. Different optimums are to be expected when any component of the system is changed; i.e., seed source, temperature, light conditions, etc. Significant increases in height growth and dry weight accumulation can be expected when plants are given additional periods of photosynthetic light (4).

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Influence of Cultivar, Season, Irrigation, and Date of Planting on Thiocyanate Ion Content in Cabbages[1]

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Abstract. **Tissue analysis of 14 cultivars of cabbage (*Brassica oleracea* L. Capitata group) in both 1974 and 1975 indicated that late maturing cultivars generally were higher in thiocyanate ion (SCN^-) content than early maturing cultivars. In both years, there was a significant positive correlation between SCN^- content of cultivars and days to maturity. While SCN^- content of late-planted (June 18, 1975) unirrigated 'Badger Market' and 'Storage Green' cabbages were more than twice as high as corresponding late-planted cabbages irrigated 5 times per week, the SCN^- content of early-planted (May 6) cabbages of both cultivars was not significantly influenced by irrigation treatment. In contrast, the marketable head fresh weight of both cultivars was lowest in late-planted, unirrigated plots. Head SCN^- content was negatively correlated with marketable head fresh weight and with total top weight of both cabbage cultivars.**

The association of goitre (enlargement of the thyroid gland) and consumption of plants of the Cruciferae family was first observed in 1928 by Chesney et al. (4) when rabbits were fed a diet with fresh cabbage leaves as the principle constituent and developed "cabbage goitre." Other studies have reported similar observations in animals (21, 23, 29, 30) but there is inconclusive evidence for this occurrence in humans (1, 19, 24).

Cruciferous plants contain a wide range of glucosinolates (thioglucosides) which yield various derivatives known to be potential goitrogens (8, 27, 29). Paxman and Hill (20) indicated that thiocyanate in kale leaves is largely responsible for thier goitrogenicity in rats. 3-indolylmethylglucosinolate (glucobrassicin) and N-methoxy-3-indolylglucosinolate (neoglucobrassicin) have been identified as the thiocyanate-yielding glucosinolates in cabbage (25), with 3-indolylglucosinolate making the major contribution (up to 68%) of glucosinolates in this species (26).

In view of concern for the content of natural toxicants in food plants (11), researchers have been studying the content, composition, and distribution of glucosinolates and their derivatives in cruciferous vegetable crops and cultivars (5, 7, 10, 16, 25, 26). We also have been studying the environmental and cultural factors influencing synthesis and accumulation of glucosinolate-derived toxins in cruciferous vegetables (2, 3, 18). In this study, we examine the influence of cultivar, season, irrigation, and planting date on thiocyanate ion (SCN^-) content in cabbages.

Materials and Methods

In 1974, 14 cultivars of cabbage (Table 1) were seeded on April 30 and grown in a greenhouse with a mean temperature of 22 ± 4°C at Macdonald College (45° 25'N; 73° 56'W). On May 28, seedlings were transplanted in the field 7 per row and within row spacing of 0.6m on a St. Bernard clay loam soil with rows 0.9m apart in a randomized block design with 3 replications. Standard recommendations for fertilizer, pesticide, and other cultural practices were followed. In 1975, the same cultivars were seeded on April 30, set in the same field on May 28, and similarly grown as the 1974 planting. In both years, 4 mature cabbages per row were selected randomly and the marketable head weight and total top weight (marketable head weight plus outer wrapper leaves) were recorded on a fresh weight basis. Thin cross-sectional wedges from each of 2 heads were removed and combined into a 100–150g sample for

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Table 1. SCN^- content of marketable heads of 14 cabbage cultivars grown in 1974 and 1975.

Cultivar	Days to maturity		Head wt (kg fresh wt)		SCN^- (μg/g dry wt)[z]	
	1974	1975	1974	1975	1974	1975
Early Greenball	49	42	0.71	0.56	184± 48	291± 45
Princess	55	48	1.21	1.09	182± 44	284± 32
Badger Market	78	55	1.74	0.83	168± 8	451± 61
Stonehead	78	55	1.81	0.78	178± 25	596±143
Canada 'Kraut	78	58	2.19	1.30	203± 18	467± 78
Copenhagen Market	84	64	2.48	1.46	276± 51	451± 93
Early Round Dutch	84	64	2.18	1.15	399± 59	660±136
Roundup Hybrid	84	64	2.37	1.28	303± 35	816± 88
Jumbo	96	75	2.36	1.82	264± 97	573±155
Penn State Ball Head	99	91	1.75	1.36	425±111	700± 95
Ultra Green	119	91	2.59	1.49	306± 64	710± 69
Storage Green	116	94	1.84	1.31	447± 75	718± 72
Evergreen Ball Head	116	94	2.10	1.44	358± 30	649± 62
Autumn Marvel	116	94	1.59	1.25	425± 96	699±156
Mean	89	71	1.92	1.22	294	576

[z]Each datum is the mean of 3 samples, each analyzed in triplicate; ± the standard error. Each sample consisted of 2 plants.

tissue analysis. The dry weight was determined from a parallel sample.

In another investigation, 'Badger Market' and 'Storage Green' cabbage, seeded in the greenhouse on April 1 and May 15, 1975, were field planted on May 6 and June 18, respectively, and grown under 2 irrigation treatments (0 and 5 times per week), applied between June 18 and final harvest of each cultivar. Soil samples were taken to the 15 cm depth on June 19, July 3, July 17, August 1, and August 20, and % soil moisture determined on a dry weight basis to compare relative differences in moisture contents of irrigated and unirrigated plots during the growing season. Plant spacing and culture were similar as described above but the field design was a split-plot with irrigation treatments replicated 3 times as main plots, date of field planting as sub-plots, and cultivar as sub-sub plots.

Each sample for tissue analysis was extracted with distilled water (1 part sample: 2 parts water, wt/vol) in a Waring blender. The crude extract (12 ml aliquots) was clarified with lead acetate ($Pb(CH_3COO)_2 \cdot 3H_2O$,0.1g) and the content of SCN^- determined colorimetrically in triplicate and expressed as μg KSCN per g dry weight of tissue as previously described (5). Since our investigations indicated that aliquots from the same crude extract with pH adjusted between 3.8 and 7.4 using 15.5 N HNO_3 or 20% NaOH and incubated at different periods up to 24 hr resulted in similar yield of SCN^- as corresponding non-adjusted aliquots (pH 6.2–6.4), we did not modify the pH of our crude extracts.

Results and Discussion

Cultivar and season. Analysis of variance indicated significant difference in SCN^- content of marketable heads among the 14 cabbage cultivars in both years tests were conducted (Table 1). There was a large variation in SCN^- content of all cultivars between years. In comparison with 1974, warmer and more erratic rainfall conditions in 1975, resulted in cabbages that were smaller by 57%, but had contents of SCN^- that were 90% greater averaged over all cultivars. Late maturing cultivars generally were higher in SCN^- content than early maturing cultivars. In fact, correlation coefficients indicated a significant relationship of SCN^- content of cultivars with days to maturity in both years (Table 2).

There also was a significant positive correlation between cultivar SCN^- content in 1974 vs. SCN^- content in 1975 (Table 2). The corresponding coefficient of determination ($100r^2$) value of 53% indicates a significant genetic component for cabbage SCN^- content.

Irrigation and planting date. Irrigation treatment × planting date interaction was significant (Table 3). For the late planting (June 18), SCN^- content of marketable heads of both cultivars grown without irrigation was more than twice as high as those of irrigated plants, whereas SCN^- contents in corresponding heads of both cultivars from the early planting (May 6) were not significantly affected by irrigation treatment.

In contrast to the head SCN^- content, the marketable head weight was lowest in late-planted, unirrigated cabbages and highest in corresponding irrigated cabbages. Head SCN^- content of both cultivars was negatively correlated with marketable head weight and total top weight (Table 4). Coefficient of determination ($100r^2$) values indicated that head weight is accountable for about 60% of the variation in head SCN^- content for both 'Badger Market' and 'Storage Green'.

Similar to the observation of VanEttan et al. (25) indicating that total glucosinolate content of cabbages within a cultivar tended to be inversely proportional to head size, we also observed this relationship when the SCN^- contents of individual heads within a cultivar were compared (Table 4). Previously we also observed (unpublished data) an inverse relationship between SCN^- content and size of Brussels sprouts along the stem of individual plants. Chong and Bible (6) reported that smaller roots of radishes, turnips, and rutabagas from plants

Table 2. Correlation of various parameters with head SCN^- content among 14 cabbage cultivars.

Variable	Year	Correlation coefficient (r)[z] Head SCN^- content 1974	1975
Days to maturity	1974	0.759**	
	1975		0.730**
Marketable head wt	1974	NS	
	1975		NS
Total top wt	1974	0.589*	
	1975		0.642*
Head SCN^- content	1974		0.730**

[z]12df.

*, **, NSSignificant at 5% (*), 1% (**) or nonsignificant (NS).

Table 3. Effect of irrigation and planting date on head SCN^- content and marketable head weight of 2 cabbage cultivars (1975).

Irrigation treatment	Planting date: Badger Market May	Badger Market June 18	Storage Green May 6	Storage Green June 18
	Head SCN^- content (μg/g dry wt)			
Unirrigated	325a[z]	870b	860a	1240b
Irrigated	245a	370a	700a	635a
	Marketable head wt (kg fresh wt)			
Unirrigated	1.30b	0.53a	1.82b	1.10a
Irrigated	1.52b	1.51b	2.55c	2.72c

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

Table 4. Correlation of head SCN^- content with marketable head weight and total top weight within each of 2 cabbage cultivars (1975).

Cultivar	Correlation coefficients[z]: SCN^- vs. marketable head wt	SCN^- vs. total top wt
Badger Market	−0.770**	−0.788**
Storage Green	−0.812**	−0.676**

[z]22df; combined data of 2 planting dates and 2 irrigation treatments. **Significant at 1% level.

Table 5. Heat unit and rainfall accumulation during the growing periods for the early- and late-planted cabbages (1975).

Variable	Planting date: Badger Market May 6	Badger Market June 18	Storage Green May 6	Storage Green June 18
Days from planting to harvest	66	54	90	87
Degree days[z] 10°C base	617	730	992	1,003
Rainfall[z] (mm)	163	175	242	258

[z]Data obtained from the official weather station at Macdonald College.

Table 6. Comparison of soil moisture contents of unirrigated and irrigated plots.

1975 sampling date	Soil moisture content (% dry wt)[z]: Unirrigated	Irrigated
June 19	14.46	16.78
July 3	16.95	19.45
July 17	13.05	17.18
August 1	13.54	19.29
August 20	10.78	18.88

[z]Each datum is the mean of 6 samples (1 per replication).

of similar age tended to have higher SCN^- contents than larger roots and that there was a direct proportionality between SCN^- content and top/root ratio of greenhouse-grown radish and turnip cultivars. In this study of cabbages, the inverse relationship between head size and head SCN^- content was observed only within (Table 4) and not among (Table 2) cultivars. Among the 14 cultivars studied (Table 1), late maturing cultivars had larger head size and higher SCN^- content. In fact, a direct proportionality was observed between total top weight and head SCN^- content among cultivars (Table 2).

The results of research conducted about 50 years ago on variation in goitrogenic potency of cabbage to rabbits bear intriguing similarities to our results reported herein. Marine et al. (13), Webster et al. (28), and McCarrison and Madhava (14) indicated that "goitrogenic power" of fall or late maturing cultivars was as much as twice as high as summer or early maturing cultivars. Apart from this variation in goitrogenicity of cabbage, Webster et al. (28) found that cabbages from the same geographic source varied in goitre producing power from year to year. Similarly, our results indicate that SCN^- content was higher in late maturing cultivars than early maturing cultivars, and that SCN^- content of cabbage grown in the same field varied from year to year. Unaware of the goitrogenicity of SCN^-, the early workers passed over it as the agent responsible for "cabbage goitre." More recently, SCN^- content of cruciferous plants has been related to their goitrogenicity (15, 17). Also Langer (12) suggests that the occurrence of SCN^- in food serves to indicate the presence of even more potent goitrogens.

Spence et al. (22) and McCarrison and Madhava (14) reported increased goitrogenic potency of cabbage during periods of high rainfall, which curiously contrasts with our finding that unirrigated cabbage had higher SCN^- contents than irrigated cabbage. While the drastic reduction in head size resulting from lack of irrigation explains the high SCN^- contents of late-planted, unirrigated plants, it is clear that heavy supplemental irrigation did not increase SCN^- content even in the late planting. Heat units and rainfall accumulated between the period of field transplanting and harvest for both cultivars were similar for both dates of planting, except that the late-planting of 'Badger Market' was exposed to more heat units than the corresponding early-planting (Table 5). Even though differences in rainfall accumulation between early and late plantings were slight (Table 5), plants of the later planting grew under greater soil moisture differentials between irrigated and unirrigated plots (Table 6). This evidence suggests that cabbage subjected to poorer growing (late-planted) conditions accumulate large amounts of basic metabolites such as sugars and amino acids which could be differentially converted to secondary metabolites, i.e. glucosinolates, rather than the expected conversion to cellulose and proteins during rapid growth. The evolutionary rationale for build up of toxic secondary metabolites when plants are under poor growing conditions, i.e. water shortages or nutrient deficiencies, as hypothesized by Janzen (9), is that the cost of herbivory to a plant should be reflected in the magnitude of the plant's investment in chemical defenses. Janzen reasoned that the cost of replacing tissues eaten by herbivores would be greater for plants growing under stress than for plants growing under more favorable conditions.

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Growth Regulator Effects on Adventitious Root Formation in Leaf Bud Cuttings of Juvenile and Mature *Ficus pumila*[1]

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Additional index words. indolebutyric acid, 6-(benzylamino)-9-(2-tetrahydropyranyl)-9H-purine, gibberellic acid, creeping fig

Abstract. **Adventitious root formation was stimulated with foliar application of indolebutyric acid (IBA) from 1000 to 1500 mg/liter for juvenile and 2000 to 3000 mg/liter for mature leaf bud cuttings of *Ficus pumila* L. IBA increased cambial activity, root initial formation, and primordia differentiation and elongation. IBA stimulated rooting when applied to juvenile cuttings at 3, 5, or 7 days after experiment initiation, but had no effect on mature cuttings when applied at day 15, the final treatment period. The interaction of IBA/gibberellic acid (GA_3) did not affect early root development stages, but reduced root elongation and quality once primorida had differentiated. IBA/6-(benzylamino)-9-(2-tetrahydropyranyl)-9H-purine (PBA) inhibited rooting at early initiation stages.**

Recent researchers have generally agreed that adventitious root formation (ARF) involve sequences of histological steps with each step having different requirements for growth substances (5, 8, 9, 10, 11). Eriksen (5) and Mohammed and Eriksen (8) found that auxins and cytokinins had different affects on ARF depending on developmental stage. Sircar (11) reported 5 different histological stages in which GA_3 and IAA alternately promoted or inhibited ARF. Hypocotyl cuttings of herbaceous annuals have been used in previous sequencing

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