

**GROWTH AND PHENOLOGY OF CABBAGE IN A WINTER PRODUCTION AREA**

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**Abstract.** Growth of cabbage from seeding through transplanting and harvest under field conditions at Sanford, Florida, followed a smooth and predictable growth curve. Fresh and dry weights of plants plotted against calendar days or cumulative degree days produced curves which could be used to quantitatively measure plant growth and compare expected with observed growth as a check on acceptable market quality.

Growth stages of cabbage are useful in monitoring crop performance and in making decisions or planning for plant protection activities to reduce costs while maintaining acceptable market quality.

The quantitative description of crop growth is both desirable and useful for several applications. Plant growth models based upon accurate phenological and growth information can provide much needed information to agriculturists (7). Simple quantitative descriptions of crop growth can also be useful to the grower and in practical integrated pest management (IPM) programs. Growers can use simple information on growth and development to monitor crop performance and to help manage the crop. In IPM programs, data on crop growth and development can be used to formulate plant protection strategies, make decisions, and determine program intensities. Consideration of cabbage growth and development may also be of value in estimating maturity and harvest dates of cabbage (6, 11).

The phenology as well as the growth and development of cabbage and related crops has been described from a botanical viewpoint especially in regard to flowering (10). Harcourt (5) has used growth stages of cabbage to formulate a life table approach to documenting pest damage. Various growth stages of cabbage are commonly referred to in pest control and cultural recommendations and scientific reports but usually have not been described in detail.

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**Materials and Methods**

Cabbage seedbeds and test plots were grown at Sanford, Florida, on Myakka Fine Sand. Seeds were planted on raised seedbeds (4 inches (10.2 cm) high) in rows spaced 6 inches (15.2 cm) apart. Seeds were spaced approximately 0.75 inch (1.9 cm) in-the-row. Seedbed areas were fertilized with 500 lb/acre (600 kg/ha) of a 5-5-8 fertilizer and treated with 2 lb/acre a.i. (2.4 kg/ha) of a phenamiphos nematicide just prior to planting. Four supplemental applications of a 20-20-20 soluble fertilizer were applied at a rate of 25 lb/acre (30 kg/ha) in 850 gal/acre (217 liters/ha) of water at weekly intervals. Seedbeds were sprayed twice weekly with a maneb fungicide and a methomyl insecticide at 1.2 and 0.5 lb/acre a.i. (1.4 and 0.6 kg/ha), respectively to control downy mildew and insects.

Fifty two days after seeding, when plants had reached the 4-5 leaf stage, they were lifted from the seedbeds and immediately transplanted in the field with a mechanical transplanter. Plants were spaced 11 inches (27.9 cm) apart in 30-inch (76 cm) rows. Field plot areas received a pre-plant application of 500 lb/acre (600 kg/ha) of a 5-5-8 fertilizer and an additional 108, 144, and 144 lb/acre (138, 184, and 184 kg/ha) of N, P2O5 and K were applied as N, P2O5, and K2O, respectively, in 3 applications spaced at about 3 week intervals as outlined in the Florida Cabbage Production Guide (8).

Field plots were fumigated 3 weeks prior to transplanting with 25 gal/acre (234 liters/ha) of a dichloropropene-dichloropropene mixture to control nematodes. Plants were sprayed weekly with a maneb fungicide and methomyl insecticide at the rates specified for seedbed protection.

Materials, and Methods

This paper reports one approach to the simple quantitative description of fresh market cabbage growth and development in a winter production area such as Florida. Phenological data and biomass accumulation were used to produce growth curves which were related to calendar days and degree days from seeding to harvest. Biomass accumulation, leaf production, and visual observation were used to identify growth stages of cabbage useful to growers and IPM scouts.

to 50 by transplant stage, 25 by cupping, and 10 by late heading. Plants sampled at early and late heading stages were cut into small pieces and dried on trays in a warm greenhouse for 5-7 days before oven drying. The entire root system was not recovered after plants reached the cupping stage. An estimated 5-10% (by weight) of the root system was not recovered. Data presented were not adjusted for this loss.

Average numbers of leaves were measured by counting the leaves on 25 plants at each sample date. Cumulative degree days were calculated by a computer program developed and adapted for Florida by Allen (1). Based on previous research results (11), minimum temperature threshold was set at 52°F (0°C) and maximum temperature threshold was 77°F (25°C).

**Results and Discussion**

Fresh and dry weights of cabbage plants sampled from seeding to harvest produced an approximately smooth, straight, curve when plotted against calendar days after seeding (Fig. 1). It was necessary to transform plant weights to log₁₀ of fresh and dry weights to handle the large changes in plant weights from seedling to mature heads. The ratio of dry to fresh weight decreased as maturity was approached but overall, remained fairly constant throughout the growth of the plant (Fig. 1).

The resulting growth curves were similar to those obtained for other cabbage cultivars. Such curves were useful for monitoring crop growth and performance. In practice, deviation from an expected growth curve could indicate plant stress or indicate the need for a revision of estimated harvest date (11). Similar growth curves have been used by the author to monitor the performance of celery crops in Florida and comparison of observed growth with expected growth can provide valuable information for the cabbage grower as well. It should be pointed out that growth and development data should be accumulated in the production area for 3-5 years before reliable use in this application.

Four distinct growth stages of cabbage from seeding to harvest were discernable when the average number of leaves per plant were monitored during the growth period (Fig. 2). To enable the comparison of growth data from different seasons and different years, average number of leaves per plant were plotted against cumulative degree days (lower temperature threshold 32°F, upper temperature threshold 77°F. The applicability of degree days to measure cabbage growth has been discussed elsewhere (11).

The four growth stages detected were: 1) Seedling—beginning with emergence to the 5-6 leaf stage. In this stage the cabbage plant is established. Leaves produced during this stage apparently do not reach a large size and are usually dropped as the plant begins to form a head. In seedbeds, severe competition from cohorts slows growth near the end of this stage. 2) Transplant—beginning at the 5-6 leaf stage and lasting through 6-8 leaf stage. Plants grow in size and new leaves begin to form a horizontal rosette type of growth. In transplanted cabbage, a period of re-establishment may slow growth and development for a period of 5-7 days during ideal conditions—longer if plants are not properly transplanted and cared for. 3) Cupping—plants have formed the basic frame that will support growth of the head. Leaves begin to enlarge and the first upright leaves that will form the protective head wrapper leaves are produced. Biomass begins to accumulate rapidly. In the cupping stage, the leaves that will appear on the harvested product are developing and plant protection activities must be adjusted accordingly. 4) Heading—the upright wrapper leaves enlarge and the head begins to develop from the inside out. The leaves that will become the outer head leaves curve over to cover the head, and like the wrapper leaves, these will appear on the harvested product and must be protected accordingly. No more leaves are evident because new ones are being produced from meristematic tissue inside the head and will continue to be produced until the head is harvested. This is a period of very rapid biomass accumulation.

The growth stages described above, along with early and late seedling and heading stages are presented in Fig. 3. Both the number of leaves and fresh and dry weight of plants, when plotted against cumulative degree days, demonstrate to some degree, the presence of these four growth stages (Fig. 2, 4, 5). Plots of fresh and dry weight show the

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**Fig. 1.** Dry and fresh weights of cabbage plants and their ratio from seeding to harvest observed for CV Rio Verde at Sanford, FL.

**Fig. 2.** Number of leaves per plant related to cumulative degree days (between 32°F and 77°F) showing four distinct growth stages of CV Rio Verde cabbage at Sanford, FL.
relative growth and biomass accumulation associated with these growth stages (Fig. 4, 5).

Classification of growth and development into growth stages and corresponding growth stage keys are valuable for monitoring and describing crop growth and for timing cultural or plant protection activities (3, 9, 11, 12). Growth stage keys have been prepared for several crops (2) and

![Early Seedling](image1)
![Late Seedling](image2)
![Transplant](image3)

**Fig. 3. Growth stage key for fresh market cabbage adapted from data of Figs. 2, 4, and 5.**

Fig. 4. Dry weight accumulation related to cumulative degree days (between 32°F and 77°F) over four growth stages from seeding to harvest of CV Rio Verde cabbage at Sanford, FL.

Harcourt has described growth stages for a life table approach for measuring pest damage to cabbage (5). The growth and phenology of cabbage and related crops have been studied and described in some detail, but the emphasis has been on bud formation and flowering (10) and may be of limited interest to growers.

Growth stage keys are also useful in all phases of IPM programs. The four growth stages described here, along with the consideration of early and late seedling and early and mature heading stages, have proven valuable for use in all phases of an experimental cabbage IPM program (3, 12) and may be of similar usefulness to growers. Similar phenological data have been used to identify the initiation of celery petioles which will appear in the harvested product and to describe the growth of celery (9) and a number of other crops. Growth stages can be used to monitor and describe crop growth and to help formulate plant protection strategies or establish the correct intensities of the program. Growth stage keys can also be helpful in projecting harvest dates (11).

Results of this study demonstrate the feasibility of simple quantitative description of cabbage growth and development that can be used by growers and in IPM and other programs. Although requirements for specific application might vary, the methods and growth stage keys presented here have proven adequate for a wide variety of applications.

**Literature Cited**

ESTIMATING FRESH MARKET CABBAGE MATURITY DATES IN A WINTER PRODUCTION AREA

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Abstract. Cabbage growth and performance data for selected hybrid cabbage cultivars over a 12-year study period were used to evaluate two methods of projecting harvest dates within individual cultivars. Projected harvest dates obtained by considering cumulative degree days or heat units [minimum temperature 32°F (0°C), maximum temperature 77°F (25°C)] demonstrated slightly less variation than projected dates based on average number of observed calendar days from transplanting to harvest. Both methods were only able to estimate harvest dates with an accuracy which ranged from 4-16 percent of the mean over a 100-110 day season depending on the cultivar. Cool or warm growing seasons, as evidenced by total degree days accumulated in December - February, were not well correlated with yield, head weight, or percent heads harvested. Neither growth days to harvest nor cumulative degree days for individual seasons were well correlated with yield, head weight, or percent heads harvested in those seasons. Well accepted cultivars exhibited less variation in yield, head weight, and percent heads harvested than poorly accepted cultivars throughout the study period. Percent harvest was the least variable of the performance variables measured over the 12-year period.

Advances in fresh market cabbage production technology will depend upon a detailed knowledge of crop growth and performance and the ability to project these parameters well before harvest. In winter production areas such as Florida, reliable information on estimating or projecting cabbage maturity dates has not been available. Often, days to harvest as specified by the seedsmen are more applicable to long days and warmer growing seasons typical of northern latitudes in the summer. These figures are not reliable in winter production areas but have been used to project harvest dates for fresh market cabbage.

An alternative approach which has been useful in other crops is to relate crop growth and development to degree days or heat unit summation (2, 3, 6, 10, 18, 20). Harvest dates of canning crops such as peas, sweet corn, tomatoes, and others have been projected on the basis of exposure of the crop to cumulative heat units or degree days coupled with an accurate knowledge of the number of heat units needed for growth and development and the optimum stage of growth for harvest (2, 10, 18, 20). This approach has also been used in modeling crop development and yield (9, 18). Although the validity of the degree day method has been questioned (9), it remains as a useful approach in modeling and in vegetable production (18). Similar criteria have been used to determine maturity of stored cabbage in New York (7), but there is no information directly applicable to fresh market cabbage in winter production areas.

We analyzed replicated cabbage cultivar performance data obtained at Sanford, Florida, between 1967 and 1979 to evaluate the applicability of average growth days to harvest and the degree day approach to projecting fresh market cabbage maturity dates. The two methods are compared and related to other variables such as yield, head weight, and percent heads harvested. The reliability of these criteria is discussed and information on the expected range in growth periods required for maturity is presented.

Materials and Methods

Cabbage cultivars were seeded by hand in seedbeds between October 5-18 of each year. Seeds were placed ½ inch (1.3 cm) apart in rows spaced 4 inches (10.2 cm) on raised beds. In 1967-74, seedbed areas were fumigated with 25 gal/acre (294 liters/ha) of a dichloropropane-dichloropropene mixture 2 weeks before planting to control nematodes. After 1974, Nemacur® was applied just prior to seeding at 2 lb/acre a.i. (2.24 kg/ha). A pre-plant broadcast of 5-5-8 fertilizer at 500 lb/acre (640 kg/ha) was made before bed formation. In some years, a supplemental application of a soluble 20-20-20 fertilizer was applied at 500 lb/acre (640 kg/ha) was made before bed formation. In some years, a supplemental application of a soluble 20-20-20 fertilizer was applied as a drench at the rate of 25 lb/acre (32 kg/ha). Routine plant protection measures were carried out in seedbeds to control insects and foliar diseases.

Plants were lifted from seedbeds after 30-40 days of growth and transplanted into the field before December 1 of each year (range November 20-30). A mechanical planter was used to space plants 11 inches (27.9 cm) apart in 30-inch (76.2 cm) rows. Plot size was 50 linear feet (15.2 m) of row replicated 4 times in a randomized complete block design. All plots were located at Sanford, Florida, on Myakka Fine Sand. Nematode control was identical to that specified for seedbeds. The fertility program outlined in the Florida Cabbage Production Guide (11) was followed each year. Although application times varied, 108, 144, and 144 lb/acre of N, P, and K (138, 184, and 184 kg/ha) were applied as N, P₂O₅, and K₂O, respectively. One or two supplemental applications of N [30 lb/acre (38.4 kg/ha)] and K₂O [30 lb/acre (38.4 kg/ha)] were required to compensate for leaching from heavy rainfall. Insecticides were