GROWTH, DEVELOPMENT AND YIELD OF WHITE CABBAGE IN RELATION TO TIME OF PLANTING

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Abstract

Experiments were carried out during two seasons to study growth, development and yield of the rather early maturing white cabbage cultivar Castello, and the late maturing cv. Bartolo, in relation to time of planting during the season. Results indicated that for both cultivars, planting late in the season resulted in a substantially reduced yield at the end of the season. When harvested at an average weight of 1.1 kg per head, effects for cv. Castello on necessary period of growth were small. The onset of rapid head growth was earlier with cv. Castello and this cultivar partitioned a greater part of total weight to the head as compared to cv. Bartolo. With planting late in the season quality of the head of cv. Bartolo was unacceptable.

1. Introduction

White cabbage (Brassica oleracea var. capitata) is an important vegetable crop in the Netherlands, the cultivation of which is mainly concentrated in the North Western part of the country. Planting is usually carried out from early April to early July, while harvesting takes place from around June/July to October/November. For the first plantings early maturing cultivars for fresh, direct marketing are used, while later on more slowly maturing cultivars for the fresh market and for winter storage are planted.

Only limited information is available as to the effect of the date of planting on yield or length of the growing period of a cabbage crop.

In America, New York, with winter storage cultivars, in one year an average yield reduction of 32 per cent was observed, when sowing was delayed from the end of May to mid June. In a second year, however, a second sowing at early June yielded 33 per cent more than a first sowing a week earlier (Isenberg et al., 1975). In south-east Scotland delayed sowing from early May to early June reduced average head dry matter yield of four late maturing cultivars grown for fodder, with 30 per cent, mainly through a reduction in percentage of plants headed. Harvesting was carried out when heads were firm. Two early maturing cultivars were not affected (Bradshaw, 1984).

In the Netherlands, with two winter storage cultivars, four plantings from early June to mid July, resulted in successively lower yields at the end of October (Anon., 1986). Maximum yield reduction observed was 86 per cent. No harvestable yield at all was obtained

with a planting after mid July. These data indicate that for the winter storage cultivars considerable yield losses can be expected when planting is substantially delayed. For the fresh market cultivars the effect of date of planting on yield is less well documented.

The present work was carried out to investigate the effect of planting date on growth, development and yield of a rather early maturing, fresh market and a late maturing winter storage type cultivar of white cabbage.

2. Material and methods

Two experiments were carried out at the experimental fields of the Research Station for Arable Farming and Field Production of Vegetables at Lelystad, on a marine loam soil. The hybrid cultivars, Castello, a rather early maturing fresh market type (Biesheuvel et al., 1988) and Bartolo, a late maturing winter storage cultivar (Biesheuvel et al., 1986) were planted at 15 May, 19 June and 15 July in 1986 and at 11 May, 15 June and 10 July in 1987, as bare-rooted transplants.

Soil tillage consisting of harrowing was carried out for the whole experimental field at the first planting. Nitrogen was applied before soil tillage, at a rate of 300 kg ha^{-1}, in the form of calcium ammonium nitrate. Phosphorus and potassium had been applied during the preceding winter season, according to site requirements based on soil analysis. Plant spacing for both cultivars was 0.60 m between the rows, with 0.50 m in the row, resulting in a plant density of 33 000 plants ha^{-1}. Nett plotsize was 5.4 m^{-2}, comprising 18 plants. At each planting date each cultivar was planted in a separate block. Standard plant protection methods were applied.

Starting at two to three weeks after each planting, at regular time intervals three plots of each cultivar were harvested by hand. All plants were separated into stem, or stalk (from approx. ground-level to apex, and after heading to just below the head), leaf-blades, leaf-stalks and head, and fresh weight of the material was determined. Dry weight of the plants parts, or with increasing bulk of subsamples, was established after oven-drying at 70°C for at least 40 hours. In the results presented dry weight of yellow leaves was not taken into account. Final harvests took place on 27 October in 1986 and on 26 October in 1987.

In 1986, at final harvest, of ten heads of each cultivar the largest width and height, and the lenght of the internal stalk was measured. Data on temperature and solar radiation were obtained from a meteorological station at approx. 6 km distance.

3. Results

3.1. Dry weight

Total as well as head dry matter production for both cultivars was higher in 1986 as compared to 1987 (figure 1), which is mainly ascribed to the generally higher average levels of radiation in 1986 (table 1). At the present planting distance cv. Castello never reached full soil cover, and a higher plant density would have resulted in a

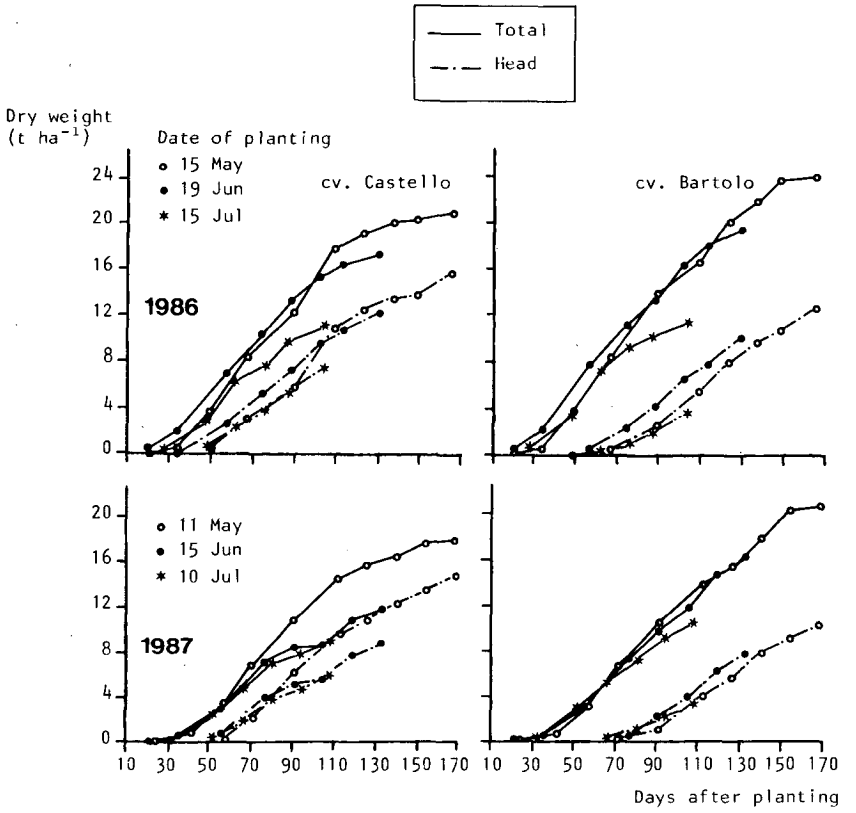

Figure 1 - Total dry weight of the crop (above-ground parts) and head dry weight.

Table 1 - Mean daily temperatures and solar radiation during the experiments.

Year	Month	May	Jun	Jul	Aug	Sep	Oct
1986	Max. temp. °C	18.4	20.5	20.9	19.5	15.6	14.8
	Min. temp. °C	7.2	9.6	11.3	9.9	6.1	5.9
	Mean temp. °C	12.9	15.4	16.7	15.0	11.1	10.7
	Mean rad. J cm^{-2}	1791	2017	1819	1494	1068	604
1987	Max. temp. °C	13.5	16.7	20.4	19.5	18.7	14.1
	Min. temp. °C	5.7	8.8	11.8	11.5	10.3	6.5
	Mean temp. °C	9.6	13.0	16.4	15.6	14.5	10.4
	Mean rad. J cm^{-2}	1552	1334	1733	1209	1075	662

higher dry matter yield.

In 1986 with both cultivars the increase in dry matter of the crop of the second planting date initially was greater as compared to that

of the first and third planting date. No such pattern was observed in 1987.

With both cultivars, especially towards final harvest, the crop of the third planting date in 1986, as well as in 1987, lagged behind in dry matter accumulation as compared to the crops of the same age of the first and second planting date.

Head dry matter yield of cv. Bartolo in each treatment was considerably lower as compared to cv. Castello. With both cultivars in each treatment head dry matter weight continued to increase until harvest.

Especially towards harvest total dry weight of plants was affected by leaf-fall.

3.2. Head development

An important factor in determining the final head yield would be the moment of onset of rapid head growth. Linear regression of head dry weight against number of days after planting (at least 96 per cent of variance accounted for) indicated the onset of rapid head growth for cv. Bartolo to be substantially later as for cv. Castello, table 2. Onset of rapid head growth for the first two planting dates in 1987 with cv. Bartolo was considerably later than at the first two planting dates in 1986. For cv. Castello onset of rapid head growth was especially early with the second planting date in 1986. Accumulated day-degrees from planting to onset of rapid head growth showed considerable variation between years, as well as between planting

Table 2 - Days after planting, date, accumulated day-degrees and photoperiodic daylenght at onset of rapid head growth.

Year, Cultivar	Date of planting	Days after planting	Date	Accumulated day-degrees		Photoperiodic daylength (h)
				0-~°C	0-20°C	
1986						
Castello	15 May	42	26 Jun	710	692	17.7
	19 Jun	34	23 Jul	635	622	16.7
	15 Jul	44	28 Aug	688	687	14.5
Bartolo	15 May	59	13 Jul	918	900	17.2
	19 Jun	55	13 Aug	942	956	15.5
	15 Jul	60	13 Sep	868	868	13.3
1987						
Castello	11 May	48	28 Jun	638	633	17.6
	15 Jun	44	29 Jul	731	725	16.4
	10 Jul	45	24 Aug	757	753	14.7
Bartolo	11 May	75	25 Jul	1034	1028	16.7
	15 Jun	73	27 Aug	1178	1169	14.5
	10 Jul	63	11 Sep	1015	1011	13.5

dates in the same year. Hara and Sonoda (1982) reported that cabbage plant growth was better when at an average temperature of 20°C as compared to 15 or 25°C. Imposing an upper limit of 20°C on the accumulated day-degrees, did not reduce the variation between heat sums however.

From the data on daylength in table 2 it is evident that the process of initiation of head formation which precedes the onset of rapid head growth, can take place under various daylenght conditions. Therefore photoperiodic effects do not appear to play a role in this process.

3.3. Dry matter partitioning

Apart from the onset of rapid head growth, the pattern of dry matter partitioning over the plant parts is important in deciding the final yield. The quantity of head dry weight as a percentage of total dry weight for both cultivars increased with time, and was considerably higher for cv. Castello as for cv. Bartolo (figure 2). With cv. Castello dry matter partitioning to the head was higher in the second and third planting, as compared to the crop of the first planting. With cv. Bartolo the percentage head dry weight in the second planting was higher as compared to the first planting, but in the third planting this percentage showed variation between the years.

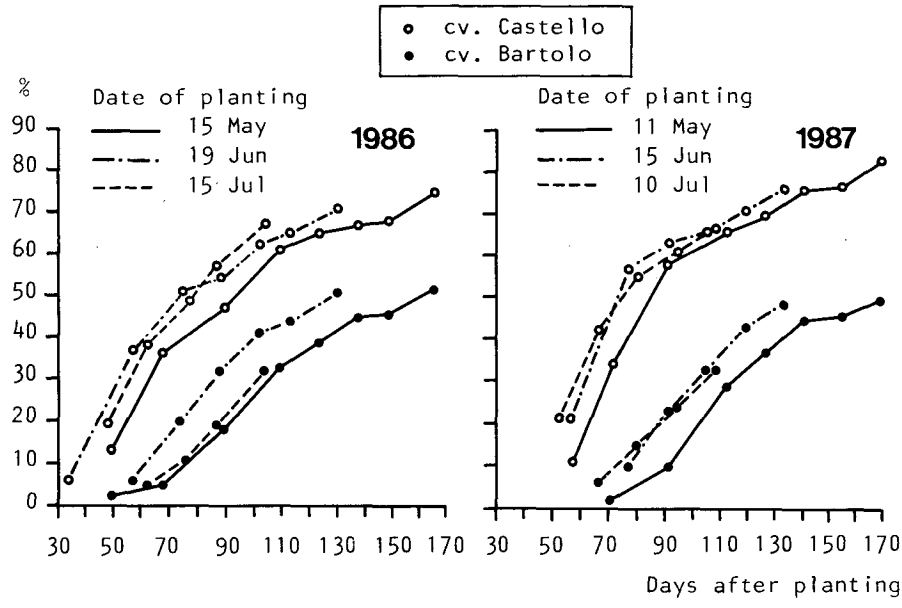

Figure 2 - Head dry weight as a percentage of total dry weight (above-ground parts).

3.4. Yield

3.4.1. Effects of planting date

Final yields in 1987 were lower compared to those in 1986 (table 3). For both cultivars in each year, the final yield declined with planting at a later date. Decrease in weight per head at final harvest was greater for cv. Bartolo as compared to cv. Castello. Percentage heads harvested was not affected by non-heading. The cultivar Castello had a considerably higher harvest index as compared to that of cv. Bartolo (see also figure 2), which contributed to the difference in yield between cultivars. Harvest indices decreased with planting

Table 3 - Yield and yield components in relation to date of planting.

Year, Cultivar	Date of planting	Harvest date	Harvest days after planting	Yield (t ha^{-1}) total	Yield (t ha^{-1}) head	Harvest index (%)	Heads harvested (%)	Weight per head (kg)
1986								
Castello	15 May	27 Oct	165	197.3	157.4	80	100	4.7
	19 Jun	27 Oct	130	173.2	126.8	73	100	3.8
	15 Jul	27 Oct	104	118.3	83.2	71	100	2.5
Bartolo	15 May	27 Oct	165	212.7	117.7	55	100	3.5
	19 Jun	27 Oct	130	186.4	99.1	53	100	3.0
	15 Jul	27 Oct	104	120.9	39.6	33	100	1.2
1987								
Castello	11 May	26 Oct	168	161.2	138.3	86	100	4.2
	15 Jun	26 Oct	133	114.7	94.1	82	100	2.8
	10 Jul	26 Oct	108	87.8	65.1	74	100	2.0
Bartolo	11 May	26 Oct	168	174.4	91.9	53	93	3.0
	15 Jun	26 Oct	133	150.6	77.4	51	98	2.4
	10 Jul	26 Oct	108	100.4	35.9	36	100	1.1

at a later date, with a sharp decrease for cv. Bartolo at the third planting date. This is attributed to the head being harvested at a comparatively young stage.

3.4.2. Yield with cv. Castello

With cv. Castello, intended for the fresh market, individual head weight at final harvest was too high for a commercially attractive product. Consumer preference is for a head weight between 0.75 and 1.50 kg (Biesheuvel et al., 1988). Highest yields with head weights between these limits are usually obtained at an average weight of 1.10 kg (Biesheuvel et al., 1988) or c.1 kg (Van Wijk et al., 1988). The number of days after planting at which an average head weight of 1.10 kg was reached by cv. Castello is presented in table 4. From these

Table 4 - Days after planting and date at which cv. Castello reached an average head weight (fresh) of 1.10 kg.

1986			1987		
Date of planting	Days after planting	Date	Date of planting	Days after planting	Date
15 May	69	23 Jul	11 May	75	25 Jul
19 Jun	62	20 Aug	15 Jun	72	26 Aug
15 Jul	70	23 Sep	10 Jul	74	22 Sep

data it is concluded that for the practical aspects of fresh market production, the effects of planting date on necessary growing period for an average head weight of 1.10 kg are small and a planting season up to mid July appears suitable for cv. Castello.

3.5. Shape of the head

The size of the head became smaller with planting at a later date in the season (table 5). With cv. Bartolo, the width of the head of the third planting date was smaller, and the head had a more or less obovate shape. In both cultivars the length of the internal stalk, as well as the length of the internal stalk relative to the height of the head, increased with planting at a later date in the season. This effect was more pronounced for cv. Castello. Quality of the head of cv. Bartolo of the third planting date was considered unacceptable because of the shape of the head and a less dense filling.

Table 5 - Measures of the head of the two cultivars at harvest in 1986.

Cultivar	Date of planting	Height (cm)	Width (cm)	Height: Width	Lenght internal stalk (cm)	Relative length int. stalk
Castello	15 May	21.0	21.4	0.99	5.1	0.24
	19 Jun	19.1	20.6	0.93	6.1	0.32
	15 Jul	17.3	18.6	0.93	9.8	0.57
Bartolo	15 May	18.8	19.5	0.97	9.3	0.50
	19 Jun	19.0	18.5	1.03	10.5	0.55
	15 Jul	18.6	14.4	1.29	12.0	0.64

4. Discussion

From the results presented above it is evident that for cv. Bartolo a delay in planting after mid May results in a lower yield at the end of October. Although the pattern of growth of the head of the crop of

the second planting date is more favourable as compared to that of the first planting date, the shorter growing season results in a lower yield. The lower yield found with the third planting date is not only brought about by a lower rate of growth and shorter growing period, but because the crop is harvested at a comparatively young stage of the head, also is due to an unfavourable harvest index. The quality of the crop of the third planting was unacceptable due to the divergent shape of the heads and a less dense filling. Our results confirm the yield and quality reduction found with delay in planting with two winter storage cultivars in North Holland (Anon.,1986). Bradshaw (1984) reported a yield reduction mainly through an increase in the number of non-heading plants. No such reduction in number of heads harvested was observed in our experiments. Isenberg et al. (1975) also found a decrease in yield with a delay in sowing in their first year of experimentation. In a second year they observed an increase in yield with a short delay in sowing, which was attributed to more favourable conditions for growth during the second growing period.

With cultivar Castello we recorded a necessary growing period of approx. 65 to 75 days to reach an average head weight of 1.10 kg. Biesheuvel et al. (1988) reported a growing period of 94 days to reach an average head weight of 1.15 kg. This period is considerably longer compared to that in our experiments. Their observations were carried out at a much higher planting density (80 000 pl ha^{-1}), which will have resulted in a lower rate of growth per plant. Van Wijk et al. (1988) reported longer necessary growth periods for optimum yields with an increase in plant density.

The planting density in our experiments was low for a commercially attractive total head yield per hectare at an average head weight of 1.10 kg. However also at higher planting densities, resulting in longer necessary growing periods, planting up to mid July is considered possible, since the growing season would only be checked near the end of October, because of increasing risk of frost damage after that time.

It is possible that the longer internal stalk with planting at a later date in the season must be ascribed to the age of the head at harvesting. The younger head possibly having a greater relative internal stalk length. Data on internal stalk length during growth of the crop to support this assumption are not available. In view of the large variation in internal stalk length with cv. Castello, and the difference in shape of the head with cv. Bartolo, it is thought however, that the observed greater internal stalk lenght with planting at a later date in the season, at least in part was caused by the low temperatures in September and October, leading to fulfillment of vernalisation requirements resulting in the onset of bolting (Heide, 1970; Wiebe, 1987). The elongation of the internal stalk with the onset of bolting in the crops of the first and second planting date, then is probably more or less inhibited by the already more firm internal structure of the heads, resulting in greater physical resistance to stalk elongation. Wiebe (1987) found that more slowly maturing cultivars require a longer period of necessary duration of vernalisation. Apart from possible differences in physical resistance to internal stalk elongation between cultivars, differences in

vernalisation requirements may also have contributed to the proportionally lesser difference in internal stalk length in cv. Bartolo.

Little information is available on the process of initiation of head formation and environmental factors influencing this process. Strandberg (1979) reported on growth and phenology of white cabbage in a winter production area. He discerned four growth stages, viz. seedling, transplant, cupping and heading, as related to leaf appearance. No discussion was made as to factors influencing the transition between these growth stages. North (1957) observed differences between cultivars in the process of reduction in rate of leaf unfolding, which occurred approximately at the time head formation began. It was concluded that reduction in rate of leaf unfolding was probably the main growth feature leading to head formation.

Our results show that the onset of rapid head growth following initiation of head formation can not be accounted for by a simple heat sum and support data presented by North (1957) on differences between cultivars in the onset of rapid head growth.

5. Conclusion

It is concluded that for an optimum yield with the winter storage cultivar Bartolo planting should not be delayed beyond the usual time around mid May. With the rather early maturing cultivar Castello, a planting season from mid May to mid July appears suitable for production of heads with a weight of approx. 1.1 kg.

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