YIELD FORMATION IN BRUSSELS SPROUTS: EFFECTS OF NITROGEN

Remmie Booij
Research Institute for Agrobiology and Soil Fertility (AB-DLO),
P.O. Box 14,
NL-6700 AA Wageningen,
Netherlands,

Keywords: biomass, *Brassica oleracea* var. *gemmifera*, Brussels sprouts, dry matter concentration, dry matter partitioning, marketable yield, nitrogen

Abstract

Data of two field experiments, in which the nitrogen application rate was varied between 0 and 300 kg/ha, were used to analyze the factors that affect marketable yield in Brussels sprouts. Marketable yield (Y) is a function of radiation use efficiency (RUE), cumulative intercepted radiation (IPAR), partitioning of biomass (P) and the dry matter concentration in the buds (DMC): Y=RUE*IPAR*P/DMC. The effect of nitrogen application rate on marketable yield was analyzed in these terms. RUE was not affected by nitrogen application rate. Nitrogen application rate had also only a small effect on P and DMC. The effect of nitrogen availability on IPAR was the key factor in determining marketable yield. It had a strong effect on canopy development resulting in increasing interception of incoming radiation at higher nitrogen application rates. Consequences for cultural measures to obtain maximum yield are discussed.

1. Introduction

Nitrogen is needed in large amounts for crop growth and plays an important role in the formation of the marketable product (Smit and Van der Werf, 1992). In commercial field vegetable production the application of nitrogen fertilizer is an important cultural measure to make production profitable. The recommended application rates are based on field trials in which the relationship between nitrogen application rate and the marketable yield was explored (Uthe, 1990). In the last decade it has become evident that excessive application of nitrogen fertilizers may negatively effect the environment (Greenwood, 1990). Low utilization of the available nitrogen by the crop results in losses to the environment due to e.g. leaching and denitrification (Smit and Van der Werf, 1992). To make field vegetable production acceptable in which nitrogen fertilizers are used, these losses should be reduced. A possibility to reduce the losses is simply a lowering of nitrogen input, but consequently this will result in lower yields. Therefore, it is necessary to develop new fertilizing strategies in which nitrogen supply is in better agreement with the dynamic nitrogen demand of the crop (Booij *et al.*, 1996b). In earlier papers (Booij et al, 1996b, 1997) effects of nitrogen availability on growth of Brussels sprouts is given, the aim of the present paper is to analyze the contribution of the separate growth components to the marketable yield.

2. Materials and methods

The analysis is based on field trials, carried out in two subsequent years. Details of the experiments are given in Booij *et al.* (1996b, 1997).

Module raised transplants of the cultivar Kundry (Sluis en Groot, Enkhuizen, NL) were transplanted during the second half of May in 1991 and 1992. Just before transplanting variable rates of nitrogen fertilizer (0-300 kg N /ha) were applied as calcium ammonium nitrate. Development of crop characteristics (LAI, fresh- and dry weight and

N content of above ground plant parts) were established by multiple harvests. The final harvest was 180 and 174 days after transplanting in 1991 and 1992 respectively (2 December and 9 November). Marketable yield consisted of buds (> 10 mm) without quality defects.

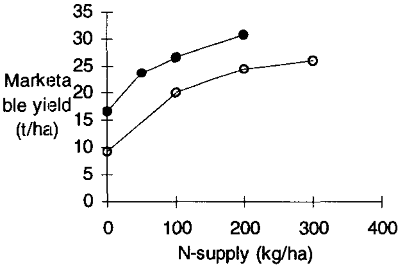
The degree of photosynthetically active radiation interception was calculated according Booij *et al.*, 1996b. Cumulative radiation interception was calculated, using radiation data from a meteorological station 1 km from the experimental field.

3. Results

Marketable yield (Y) is a function of total biomass (B), partitioning of biomass (P) and dry matter concentration in the buds (DMC). Total biomass (B) is a function of cumulative intercepted radiation (IPAR) and radiation use efficiency (RUE), (Spitters, 1990). So: Y= IPAR*RUE*P/DMC. In the following, the contributions of the different components to marketable yield were analyzed.

3.1. Marketable yield

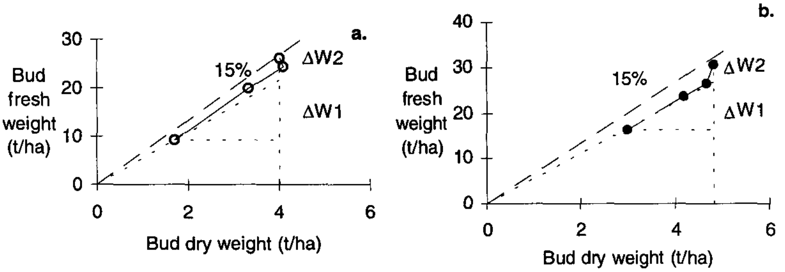
Figure 1.
The effect of nitrogen application rate on marketable bud yield in 1991(O) and 1992(●).



At the final harvest fresh marketable yield increased with increasing nitrogen application rate (Figure 1). Yield increase diminished with increasing N supply. The maximum yield level was 20-30 tons per ha at the highest N-application rate, while the yield obtained without fertilizer application was only 7-16 ton/ha. Yields in 1991 were significantly lower than in 1992.

3.2. Bud dry weight

Figure 2.
Relationship between bud dry weight and bud fresh weight at the final harvest at increasing nitrogen application rates in 1991 (a) and 1992 (b). Broken line indicates a dry matter concentration of 15%. ΔW1 indicates the fresh weight increase only due to a bud dry weight increase and ΔW2 the additional weight increase due to a decrease in dry matter concentration. Data points are connected (solid line) according increasing nitrogen application rate.

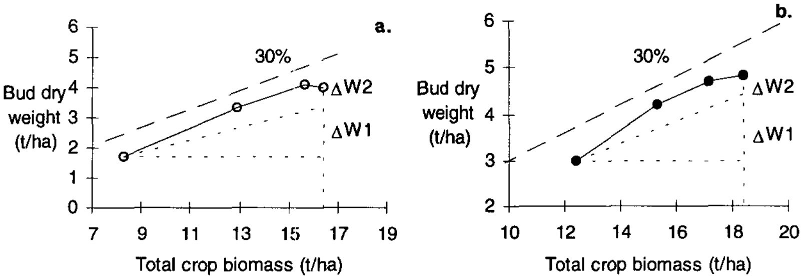


Fresh bud yield is a now a function of total bud dry weight and the water content of the buds. Total fresh bud yield increased strongly with the total bud dry weight (Figure 2). With increasing nitrogen application rate, bud fresh weight increased stronger than bud dry weight, resulting in a dry matter concentration decreasing from 20% at the lowest N-supply to 15% at the highest application rate. Especially at the highest levels of N-supply a strong decrease in dry matter concentration was observed (Figure 2). So fresh bud yield increase with increasing N-supply, was due to an increase in bud dry weight and a decreasing dry matter concentration. The contribution of these two factors to fresh bud weight, when N-supply is increased from the lowest up to the highest application rate can be separated as is shown in Figure 2. Assuming no effect of increasing N-supply on dry matter concentration, bud fresh weight increase is only due to bud dry weight increase (ΔW1 in Figure 2). ΔW2 represents the additional increase due to the decrease in dry matter concentration (Figure 2). From Figure 2 can be concluded that the increase in marketable yield, when nitrogen application rate was increased from no nitrogen up to the highest application rate, was mainly due to an increase in bud dry weight. However, with increasing nitrogen application rate the contribution of bud dry weight increase to marketable yield became less and that of water content became more (Fig. 2)

3.3. Total crop biomass

Figure 3

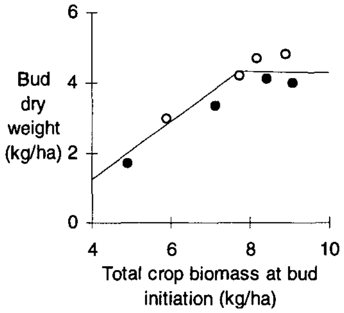
Relationship between total crop biomass and bud dry weight at the final harvest at increasing nitrogen application rates in 1991 (a) and 1992 (b). Broke line indicates a dry matter partitioning of 30% towards the buds. ΔW1 indicates the bud dry weight increase due to a crop biomass increase and ΔW2 the additional weight increase due to a change in partitioning. Data points are connected (solid line) according increasing nitrogen application rate.



Total bud dry weight is a function of the total crop biomass and the partitioning of biomass between marketable product and the remaining of the crop (crop residue). Figure 3 shows that bud biomass increased with increasing total crop biomass. About 16-20% of the total biomass was recovered in the buds, when no nitrogen fertilizer was applied and increased up to 25-30% at the higher levels, followed by a slight decrease again (Figure 3). A similar approach was now applied as shown for the water content (Figure 2), showing an effect of nitrogen application rate without (ΔW1) and with (ΔW2) an effect of nitrogen application rate on partitioning. It appeared that the main effect of nitrogen application rate on bud weight was through its effect on total crop biomass (Figure 3). There was even a direct relationship between total crop biomass at the time of bud initiation and the final bud yield (Figure 4). Final bud dry weight increased with increasing total crop biomass at bud initiation until the effect was leveled off at a total crop biomass higher than 7.5 ton/ha at bud initiation (Figure 4). Total crop biomass is a function of the accumulated intercepted Photosynthetically Active Radiation (PAR) and the Radiation Use Efficiency (RUE).

Figure 4

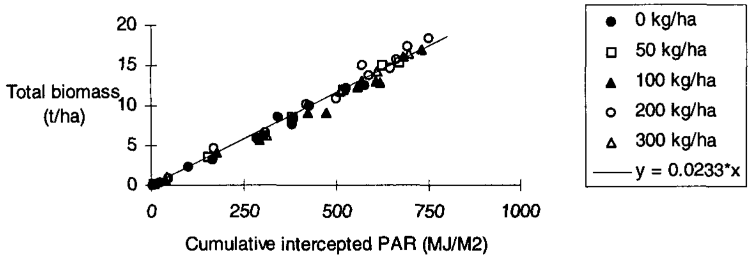
Relationship between total crop biomass at initiation of the buds and bud dry weight at the final harvest in 1991(O) and 1992(●).



3.4. Accumulated intercepted radiation

Figure 5

Relationship between cumulative PAR and the total crop biomass. Line is best fitting line for all application rates.

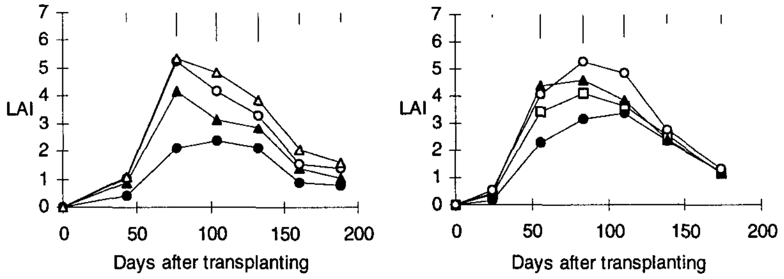


The total crop biomass increased linearly with the accumulated PAR (Figure 5). The slopes of the relationship for the separate N-rates did not significantly differ for the different N application rates. As the slope of this relationship represents the RUE (Spitters, 1990), it means that the effect of nitrogen application rate on total crop biomass production was through the effect on accumulation of intercepted radiation.

3.5. Canopy development

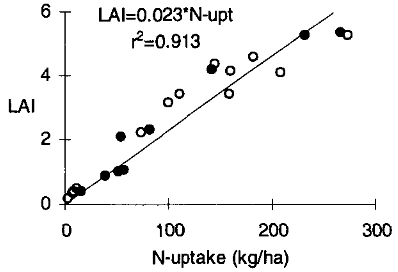
Figure 6

Effect of nitrogen application rate on development of leaf area (LAI). For legend see Figure 6. Vertical bars indicate LSD(0.05)



The accumulation of intercepted radiation is a function of incoming radiation and crop canopy development. Nitrogen application rate had a large effect on the canopy development (Figure 6). Leaf area expanded faster at the higher N-application rates and a higher Leaf Area Index (LAI) was reached at the high application rates. Leaf area duration, represented by the area below the curves, was much higher for the higher nitrogen application rates. So nitrogen availability had a main effect on biomass accumulation through its effect on development of leaf area. This is also shown by the relationship between the total nitrogen uptake by the crop and the development of LAI (Figure 7). Nitrogen uptake until maximum leaf area was reached, increased linearly with leaf area development (Figure 7). This relationship did not depend on the nitrogen application rate and was the same for both years.

Figure 7
Relationship between nitrogen uptake and Leaf Area Index in 1991 (O) and 1992(●)



4. Discussion

The present analysis showed that the nitrogen fertilizer application rate mainly affected marketable bud yield through an effect on the development of leaf area which resulted in a higher total crop biomass production (Figure 2, 3, 5, 6). Water content of the buds increased most clearly at the highest nitrogen application rates (Figure 2). Especially at a higher nitrogen availability nitrogen uptake increased stronger than dry matter production, resulting in a strong increase in the percentage of nitrogen in the crop (Booij *et al.*, 1996b). The higher percentage of nitrogen in the dry matter means a higher protein content, which may result in a higher water content. Although this increase in water content due to an increase in nitrogen application rate contributed relatively less to the total yield increase, than the increase in bud dry weight, it is likely to be economically significant. As an increase of nitrogen application rate is viable as long as the costs of the additional fertilizer application are less than the accompanied yield increase (Booij *et al.*, 1994).

Additionally the higher nitrogen concentration results in a greener appearance of the buds (Booij *et al.*, 1997) due to a higher chlorophyll content of the leaves (Booij *et al.*, 1996a). The green color of the buds is an important quality characteristic. The effects of nitrogen application rate on both aspects (water content and color) are in a range of nitrogen uptake rates that hardly result in a higher biomass production (Booij *et al.*, 1996b). The nitrogen uptake needed to obtain a greener appearance and a higher fresh bud yield, as a result of a higher water content is, therefore, due to luxury consumption of nitrogen. This nitrogen uptake at high application rates is not important for biomass production, but is significant in commercial production (Booij *et al.*, 1994). From an environmental point of view this is less acceptable, because the higher application rates result in higher amounts of nitrogen in the crop residue (Booij *et al.*, 1997). These crop residues have a lower C/N ratio due to an increase in the percentage of nitrogen. A lower C/N ratio results in an easier release of mineral nitrogen during decomposition of the crop residue (Whitmore, 1996), which is susceptible to a post-harvest leaching from the soil.

Final bud yield correlated strongly with the amount of biomass present at the initiation of bud growth (Figure 4). As time of bud initiation is hardly affected by nitrogen application rate (Booij *et al.*, 1997), nitrogen management should be aimed at obtaining maximum biomass at the time of bud initiation. The relationship between biomass at bud initiation and final bud dry weight can be due to two aspects: 1) a higher biomass at bud initiation means that more biomass is available for redistribution, to support bud growth and, 2) a higher biomass at bud initiation is accompanied by a larger leaf area, so that radiation interception is higher and lasts longer. Nitrogen application rates should, therefore, aim at achieving a total biomass sufficient to support subsequent bud growth. This means that so much nitrogen should be applied at transplanting that sufficient biomass can be produced before bud initiation (approx. 8 tons/ha) to achieve the required bud yield (25-30 tons/ha).

Acknowledgements

Dr A.P. Everaarts (PAV) and Dr A.J. Haverkort (AB-DLO) are kindly thanked for their comments on earlier drafts of the manuscript.

References

Booij, R., C.T. Enserink, A.L. Smit, and A. Van der Werf. 1994. Nitrogen fluxes in the crop-soil system of Brussels sprouts and leek In: P.C. Struik, W.J. Vredenberg, J.A. Renkema and J.E. Parlevliet (eds.), Plant production on the threshold of a new century, pp. 179-185

Booij, R, P. De Willigen, A.D.H. Kreuzer, A.L. Smit, and A. Van der Werf. 1996a. Nitrogen balances during growth of Brussels sprouts and leeks, Acta Horticulturae. 428: 31-43.

Booij, R., A.D.H. Kreuzer, A.L. Smit, and A. Van der Werf. 1996b. Effect of nitrogen availability on dry matter production, nitrogen uptake and light interception of Brussels sprouts and leeks. *Netherlands Journal of Agricultural Science.* 44: 3-19.

Booij, R., A.D.H. Kreuzer, A.L. Smit, and A. Van der Werf . 1997. Effects of nitrogen availability on the biomass and nitrogen partitioning in Brussels sprouts (*Brassica oleracea* var. *gemmifera*) *Journal of Horticultural Science.* 72: 285-297.

Greenwood, D.J. 1990. Production or productivity: The nitrate problem? *Annals of Applied Biology.* 117:209-231.

Smit, A.L. and A. Van der Werf. 1992. Physiology of nitrogen uptake and utilization. (In Dutch) In: H.G. Van der Meer and J.H.J. Spiertz (Eds.). Stikstofstromen in agroecosystemen. Agrobiologische Thema's no. 6, DLO-Centrum voor Agrobiologisch Onderzoek (CABO-DLO), Wageningen, pp. 51-69.

Spitters, C.T.J. 1990. Crop growth models: their usefulness and limitations. Acta Horticulturae. 267: 349-368.

Uthe, R. 1990. Auswertung von Stickstoffdüngungsversuchen bei Gemüse mit dem Linear Response and Plateau Modell. *Gartenbauwissenschaft.* 55:247-251.

Whitmore, A.P. 1996. Modeling the release and loss of nitrogen after the incorporation of vegetable crop residues. *Netherlands Journal of Agricultural Science.* 44: 73-86.