Gartenbauwissenschaft, **65** (1). S. 30–34, 2000, ISSN 0016–478X. © Verlag Eugen Ulmer GmbH & Co., Stuttgart

Effects of Nitrogen on Yield Components of Brussels Sprouts (Brassica oleracea L. var. gemmifera DC.)

Wirkung von Stickstoff auf Ertragskomponenten von Rosenkohl (Brassica oleracea var. gemmifera)

R. Booij
(Research Institute for Agrobiology and Soil Fertility, Wageningen)

Summary

Data of two field experiments with Brussels sprouts *(Brassica oleracea* var. *gemmifera)*, with nitrogen application rates between 0 and 300 kg/ha, were analyzed to establish the effect of nitrogen on the components of marketable yield. 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, while this only had 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 due to an increasing 'leaf area duration' (LAD) with increasing nitrogen availability. Consequences for crop management to obtain maximum yield are discussed.

Zusammenfassung

Zwei Feldversuche mit Rosenkohl wurden durchgeführt, um den Effekt von verschiedenen Stickstoffgaben (0 bis 300 kg pro ha) auf die Komponenten des marktfähigen Ertrags festzustellen. Der marktfähige Ertrag (Y) ist eine Funktion der Lichtnutzungseffizienz (RUE), der absorbierten Strahlungsmenge (IPAR), der Verteilung der Trockenmasse (P) und dem Trockensubstanzgehalt der Röschen (DMC).

$$Y=RUE*IPAR*P/DMC$$

Die Wirkung der N-Gabe auf den marktfähigen Ertrag wurde wie folgt analysiert: RUE wurde durch die N-Gabe nicht beeinflusst. Die Stickstoffgabe hatte nur einen geringen Effekt auf die Verteilung der Trockenmasse und den Trockensubstanzgehalt der Röschen. Der Zusammenhang zwischen der N-Gabe und IPAR erklärte am besten den marktfähigen Ertrag. Die N-Versorgung hat einen grossen Einfluss auf die Entwicklung der Blattfläche (LAI), was eine Zunahme der aufgenommenen Strahlung zur Folge hatte. Mit zunehmender Stickstoffgabe wurde außerdem die Blattflächendauer (LAD) stark erhöht. Die Schlussfolgerungen für die Maximierung der Erträge von Rosenkohl werden diskutiert.

Introduction

Nitrogen is needed in large amounts for crop growth and it 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 important 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 affect the environment (GREENWOOD 1990). Low utilisation 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 nitrogen fertilizer application in field vegetable production acceptable, these losses should be reduced. A possibility to reduce losses is simply a lowering of nitrogen input, but this will result in lower yields. Therefore, it is necessary to develop new fertilization strategies in which nitrogen supply better matches the dynamic nitrogen demand of the crop (BOOIJ et al. 1996b). In earlier papers (BOOIJ et al 1996b, 1997) effects of nitrogen availability on crop growth of Brussels sprouts are given. The aim of the present paper is to analyze the contribution of the separate growth components to the marketable yield.

Materials and Methods

The analysis is based on field trials, carried out in two subsequent years (1991 and 1992). 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 at a plant density of 3.3 plants m^{-2}. Just before transplanting different rates of nitrogen fertilizer (0–300 kg N /ha) were applied as calcium ammonium nitrate. Canopy development (LAI) was determined by six consecutive harvests during the period of crop growth using a Li-cor 3100 area meter (Li-cor, Lincoln). Leaf area duration (LAD) was calculated according to HUNT

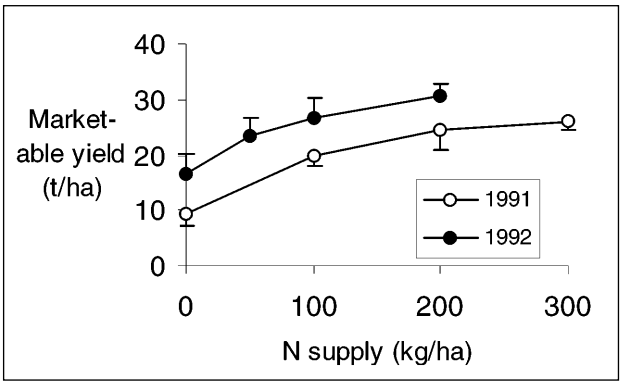


Fig. 1. Effect of nitrogen application rate on marketable bud yield in 1991 and 1992. Vertical bars indicate + or – sem.
Wirkung der Stickstoffgabe auf den marktfähigen Ertrag von Rosenkohl.

(1982). The final harvest was 180 and 174 days after transplanting in 1991 and 1992, respectively (2 December and 9 November). At final harvest marketable bud yield and dry matter concentration of the buds and total crop biomass were determined. The last parameters included biomass in the shed leaves, which were collected weekly. Marketable yield consisted of buds (> 10 mm) without quality defects.

The degree of photosynthetically active radiation interception was calculated according to BOOIJ et al.(1996b), using the percentage of ground cover as input. Ground cover was established according HAVERKORT and HARRIS (1986). Cumulative radiation interception was calculated, using radiation data from a meteorological station 1 km from the experimental field.

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 are analyzed.

Marketable yield

At 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 t per ha at the highest N application rate, while the yield obtained without fertilizer application was only 7–16 t/ha. Yields in 1991 were significantly lower than in 1992.

Bud dry weight

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 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 N levels there was a strong decrease in dry matter concentration (Figure 2). So the 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 to the highest application rate can be separated as is shown in

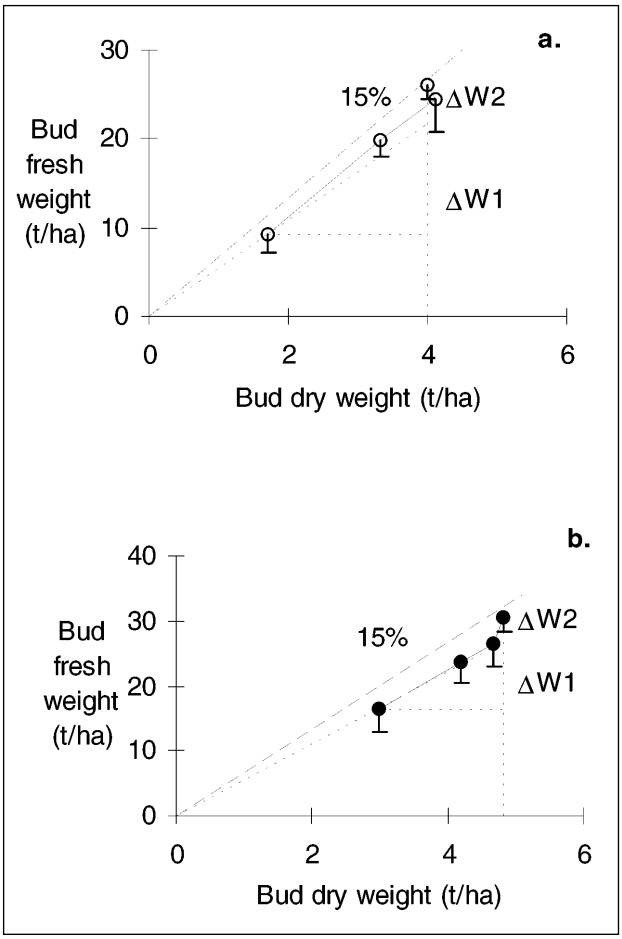


Fig. 2. Relationship between bud dry weight and bud fresh weight at final harvest at increasing nitrogen application rates in 1991 (a) and 1992 (b). The broken line (— —) indicates a dry matter concentration of 15%. ΔW1 indicates the fresh weight increase due to a bud dry weight increase only and ΔW2 the additional weight increase due to a decrease in dry matter concentration. Data points are connected (solid line) according to increasing nitrogen application rate. Vertical bars indicate + or – sem.
Beziehung zwischen der Trockenmasse und der Frischmasse der Rosenkohlröschen bei der Endernte nach steigender Stickstoffgabe 1991 (a) und 1992 (b). Die gestrichelte Linie zeigt einen Trockensubstanzgehalt von 15%. ΔW1 zeigt den Anstieg der Frischmasse, der allein durch den Anstieg der Trockenmasse verursacht wird. ΔW2 zeigt den zusätzlichen Anstieg der Frischmasse infolge abnehmender Trockensubstanzgehalte.

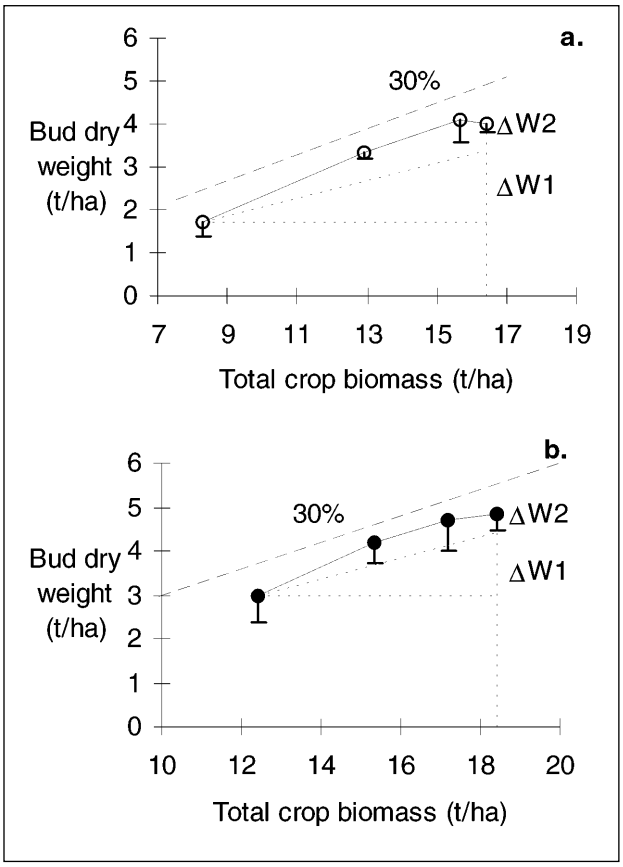


Fig. 3. Relationship between total crop biomass and bud dry weight at final harvest at increasing nitrogen application rates in 1991 (a) and 1992 (b). The broke line (— —) indicates a dry matter partitioning of 30% towards the buds. ΔW1 indicates the bud dry weight increase only due to a crop biomass increase and ΔW2 the additional weight increase due to a change in partitioning. Data points are connected (solid line) according to increasing nitrogen application rate. Vertical bars indicate + or – sem.
Beziehung zwischen Gesamtpflanzenmasse und der Trockenmasse der Röschen bei der Endernte nach steigender Stickstoffgabe 1991 (a) und 1992 (b).

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). Figure 2 shows that the increase in marketable yield, when the nitrogen application rate was increased from no nitrogen 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 reduced and that of water content increased (Figure 2). Only at the highest nitrogen application rate ΔW2 was significant ($P < 0.05$) (Figure 2).

Total crop biomass

Total bud dry weight is a function of the total crop biomass and the partitioning of biomass between marketable product and the non-marketable parts (crop residue). In our trial total biomass included total biomass in dropped leaves. Figure 3 shows that bud biomass increased with increasing 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 nitrogen levels, followed by a slight decrease (Figure 3). A similar approach was now followed as for the water content (Figure 2), showing an effect of nitrogen application rate without (ΔW1) and with (ΔW2) the effect of nitrogen application rate on partitioning. The main effect of nitrogen application rate on bud weight was found to be through its effect on total crop biomass (Figure 3). Only in 1991 the effect of nitrogen availability on partitioning contributed significantly to bud dry weight (Figure 3).

Total crop biomass is a function of the accumulated intercepted Photosynthetically Active Radiation (PAR) and the Radiation Use Efficiency (RUE).

Accumulated intercepted radiation

Total crop biomass increased linearly with the accumulated PAR (Figure 4). The slopes of the relationship for the separate N rates did not significantly differ for the various 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.

Canopy development

The accumulation of intercepted radiation is a function of incoming radiation and crop canopy development.

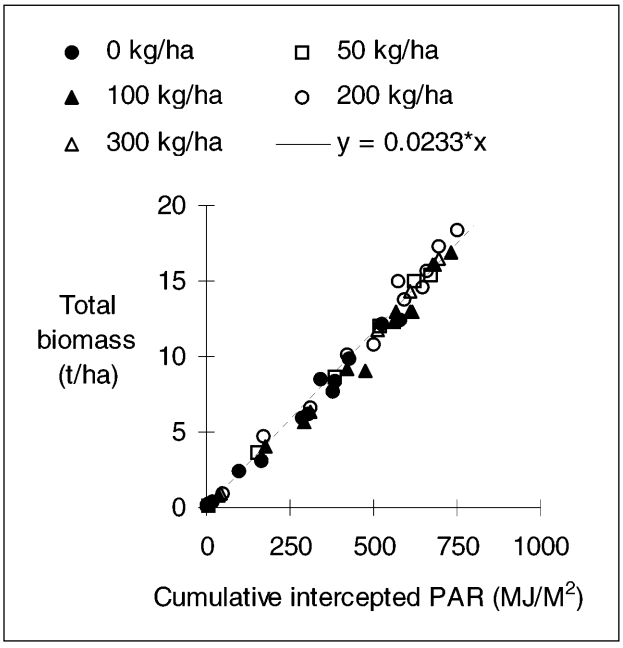


Fig. 4. Relationship between cumulative intercepted Photosynthetically Active Radiation (PAR) and the total crop biomass. Line is best fitting line for all application rates.
Beziehung zwischen der absorbierten photosynthetisch aktiven Strahlungsmenge (PAR) und der Gesamtpflanzenmasse.

Nitrogen application rate had a large effect on canopy development. Leaf area expanded faster at the higher N application rates and a higher maximum Leaf Area Index (LAI) was reached at the higher rates. Leaf area duration now represents the area beneath the LAI versus time curve (HUNT 1982). The leaf area duration (LAD) increased with increasing nitrogen application rate (Figure 5). This means that the main effect of nitrogen availability on biomass accumulation was through its effect on leaf area development.

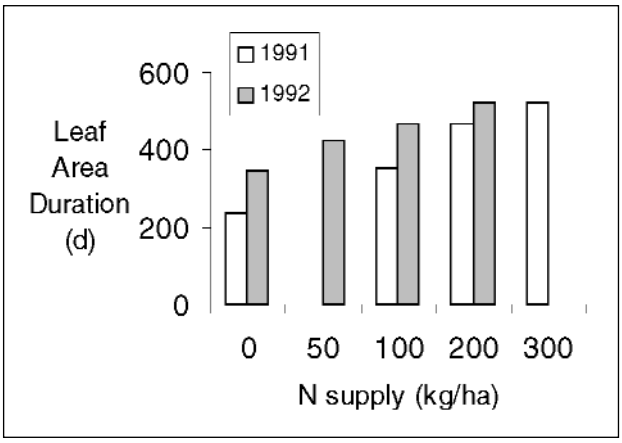


Fig. 5. Effects of nitrogen application rate on 'leaf area duration' (LAD).
Wirkung der Stickstoffgabe auf die Blattflächendauer (LAD).

Discussion

The present analysis shows 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 (Figures 4, 5). Effects of nitrogen on dry matter partitioning, dry matter concentration and radiation use efficiency (RUE) were less important (Figures 2, 3, 4). 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 crop nitrogen concentration (BOOIJ et al. 1996b). The higher nitrogen concentration in the dry matter means a higher protein content, which may result in a higher water content. Although such an increase was less important for the total yield increase than the increase in bud dry weight, it is likely to be economically significant. An increase in nitrogen application rate is viable as long as the costs of the additional fertilizer application are lower than the resulting yield increase (BOOIJ et al. 1994).

In addition, the higher nitrogen concentration results in greener buds (BOOIJ et al. 1997) due to a higher chlorophyll content of the leaves (BOOIJ et al. 1996a). The green colour of the buds is an important quality characteristic. The effects of nitrogen application rate on both aspects (water content and colour) are in a range of nitrogen uptake rates that hardly increase 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, therefore, is 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 nitrogen concentration. A lower C/N ratio results in an easier release of mineral nitrogen during crop residue decomposition (WHITMORE 1996), which is available for post-harvest leaching of nitrate.

Final bud yield correlated strongly with the amount of biomass present at the initiation of bud growth (BOOIJ et al. 1997). As the 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 cumulative radiation interception is higher due to a larger leaf area duration (Figure 5). 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 t/ha) to achieve the required bud yield (25–30 t/ha).

Thanks are due to Dr A.P. Everaarts (PAV) and Dr A. J. Haverkort (AB-DLO) for their comment on earlier drafts of the manuscript and to Mr H. Terburg for corrections of the language.

Literature

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, Wageningen, 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.

HAVERKORT, A. J. and P. M. HARRIS 1986: Conversion coefficients between intercepted solar radiation and

tuber yield of potato crops under tropical highland conditions. Potato Research **29**, 529–589.

HUNT, R. 1982: Plant growth curves. The functional approach to plant growth analysis. Edward Arnold, London, 248 pp.

SMIT, A. L. and A. VAN DER WERF 1992: Physiology of nitrogen uptake and utilisation. (In Dutch) In: H. G. VAN DER MEER and J. H. J. SPIERTZ (eds.),. Stikstofstromen in Agro-ecosystemen. 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: Modelling the release and loss of nitrogen after the incorporation of vegetable crop residues. Netherlands Journal of Agricultural Science **44**, 73–86.

Eingegangen: 19.6.1998/14.10.1998

Dr R. Booij, Forschungsinstitut für Agrobiologie und Bodenfruchtbarkeit, Postfach 14, NL-6700 AA Wageningen, die Niederlande.