# Influence of row covers on soil loss and plant growth in white cabbage cultivation

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**ABSTRACT**

Row covers are usually used to protect plants from insects and cold temperatures, and to accelerate plant growth. But they could also serve as an erosion control strategy. For this reason, fleece (FC) and net covers (NC) in white cabbage (*Brassica oleracea* convar. *capitata* (L.) Alef. var. *capitata* L. f. *alba*) cultivation were tested in a two-year field experiment to determine effects on soil erosion, plant growth and plant diseases. Soil loss under FC was reduced on average by 76% and under NC by 48% compared to the non-covered control treatment (CO). Soil temperature did not differ significantly in either of the experimental years between the treatments and ranged from 17.2–18.2°C in 2012 and from 18.7–18.9°C in 2013. Soil moisture content, air temperature and relative humidity were always highest under FC, followed by NC and CO. Leaf area index was also highest under FC across all sampling dates. The fresh matter head yield under FC and NC was significantly higher (80 t/ha) compared to CO (66 t/ha) in 2012. An opposite result was detected in 2013, with the highest yield in CO (64 t/ha) and lowest under FC (53 t/ha). Overall, for moderate climate conditions, the row covers seem to be beneficial as a suitable erosion control strategy.

**Keywords**: microclimate; soil erosion; agrotextiles; vegetables; artificial rainfall experiment

Soil erosion is a devastating problem throughout the world. The tolerable rate of soil losses by wind or water erosion in Europe is estimated to be less than 1.0 t/ha/year (Jones et al. 2004). Cumulative mean soil erosion rates in tilled agriculture in Europe are between 4.5 and 38.8 t/ha/year. In Europe, 115 Mio. ha of land are at high risk of water erosion and 42 Mio. ha of wind erosion (European Environment Agency 1998). In vegetable production systems, the tillage intensity is often high, with at least one pass by the mouldboard plough in autumn and two passes in spring by rotary harrow. The consequences are bare fields with unstable, finely structured soils accompanied by a very high risk of soil erosion and soil degradation. Conservation tillage (non-inversion tillage, no-tillage) can reduce the erosion, because of a mulch layer, which prevents the soil against the high energy of raindrops or against wind (Lal 2000). For vegetable production, especially for transplants, there are up to now only very few technical solutions for conservation tillage such as reduced tillage or no-tillage. Furthermore vegetable transplants are dependent on a finely crumbled seedbed for optimal growth conditions, which can hardly be achieved by non-inversion or no-till. All in all, the high erosion risk, due to wide row distances (> 45 cm) and late soil covering by the plants requires an erosion control strategy. The use of row covers (agrotextiles, direct covers, crop covers) could be used to prevent water erosion. Non-woven fabrics (e.g. fleece) are fielded for frost protection in spring and to accelerate plant growth. Insect netting or mesh cover are normally used in organic agriculture to protect crops against insect pests (Rekika et al. 2009, Olle and Bender 2010). However, the agrotextiles can be used as an erosion control measure, because the erosive energy of raindrops is reduced if the soil is covered by row covers (Davies et al. 2006).

In Central Europe, white cabbage (*Brassica oleracea* convar. *capitata* (L.) Alef. var. *capitata* L. f. *alba*) is usually transplanted in April or May. The soil covering by leaves does not occur before the end of June or beginning of July. During these months, the frequency of heavy rainfall events is particularly high accompanied with a high soil erosion risk. At the same time, June and July are the warmest months in the year, so the microclimate under row covers can be modified, resulting in higher air and soil temperatures, higher relative humidity, and lower irradiance compared to open-air conditions in non-covered plots (Mermier et al. 1995, Gimenez et al. 2002). When row covers are used as erosion control measures, in contrast to the original use as frost protection and against insect pests, the covering is over an extended period and over a latter part of the year. The effect on the plant development of white cabbage under row covers in summer is not yet known, so the objectives of the study were to determine the erosion protective potential of different covers in white cabbage and to investigate the microclimate and its influence on plant growth, yield and on plant diseases.

## MATERIAL AND METHODS

To determine the soil erosion protective potential of the different row covers in July 2012 and rainfall simulation (RS) was conducted three times at the research station belonging to the University of Hohenheim, 'Hohenheim Gardens' (48°42'42''N, 9°11'57''E). The artificial rainfall was generated by an irrigation system with a rainfall intensity of 25 mm/h and a Christiansen's coefficient of uniformity of 94% (Christiansen 1942). There were six bare plots with two different slopes (12% and 18%) and a plot size of 3 m × 1 m. One plot per slope was covered by insect netting with a mesh diameter of 1.35 mm × 1.35 mm (Rantai K; NC), the other one with a polypropylene, 17 g-density, non-woven fabric (fleece; FC) and the third treatment was the non-covered control (CO). The soil type was a stagnogleyic Cambisol and the soil texture was a clay loam (CL; FAO 2006). The soil-water suspension was collected at the end of the plot in collecting boxes. After the simulation (rainfall duration: 2 h) the suspension was filtered and the amount of water was measured. The soil filtrate was weighed, dried at 105°C until a constant weight was achieved, and re-weighed.

The field experiment (FE) was carried out in 2012 and 2013 on the experimental station belonging to the University of Hohenheim at Ihinger Hof in Southwest Germany (48°44'40''N, 8°55'26''E). The average temperature was 9.3°C in 2012 and 8.7°C in 2013. The rainfall in 2012 was 728 mm and in 2013 it was 922 mm. The soil type was a Haplic Cambisol Ruptic (Loess above Upper Trassic). In the upper layer (0–20 cm) the soil texture was a silt loam (SiL) and the second layer (deeper 20 cm) represented loam (L; FAO 2006). White cabbage cv. Kalorama was transplanted (14/5/12 and 15/5/13; row distance: 50 cm) in a randomized complete block design with 3 treatments and 3 replicates with a plot size of 20 m × 2 m. Soil preparation was done by a mouldboard plough in autumn 2011 and 2012, and by a rotary harrow one day before transplanting in spring. The treatments were, similar to the RS experiment, fleece cover, net cover and non-covered control. Fertilizer application to a target value of 270 kg N/ha (ENTEC Perfect, 15% N + 2% P + 17% K), weed and pest control were done according to the best management practice in all treatments.

Soil temperature and soil moisture were determined by a soil thermometer (testo 925, Test AG, Lenzkirch, Germany) and a TDR probe (TRIME-FM, IMKO, Micromodultechnik, Ettlingen, Germany) once a week in the year 2012. In 2013, permanent sensors were installed in all plots to record air temperature (Tinytag Plus 2, Gemini Data Loggers, West Sussex, UK), relative humidity of the air (Tinytag Plus 2, Gemini Data Loggers, West Sussex, UK), soil moisture (DECAGON Echo-5, Dacagon Devices, Pullman, USA) and soil temperature (Thermistor, 6507B/30, Unidata Europe (Starlog), Neustadt, Germany) under FC, NC and CO from transplanting up to removing the covers.

Plant samples were taken in 2012 and 2013 in all plots biweekly until the direct covers were removed (2012: 99 days after transplanting (DAP); 2013: 63 DAP). Three (2012), or five (2013) plants per plot were harvested to determine leaf area index (LAI; was measured 3 times; LI-3100 Area Meter; LI-COR, Lincoln, USA) and dry weight (DW) per plant by drying the samples at 60°C.

For determination of pests and diseases, a visual rating of cabbage plants was conducted on the day of the cover removal in both years. Every single cabbage plant was verified, according to symptoms of frequently occurred cabbage diseases. Infected plants were counted and plant samples were taken for microscopic analysis of the pathogen.

At harvest time (2012: 138 DAP, 2013: 148 DAP) 15 plants per plot were harvested by cutting off the aboveground biomass. This was done in order to determine the fresh matter (FM) yield of the whole plant and the FM head yield as a measure of the marketable yield. Harvest index was calculated by division of the head weight by the total aboveground biomass per plant.

Statistical analyses were conducted with SAS (SAS/Stat 2009). The statistical significance of differences in mean values of LAI, DW per plant, FM yield and harvest index were analyzed with the SAS procedure Proc Mixed, whereby treatment and replicates were given as fixed effects and the sampling position and plot were given as random effects. Different sampling dates were analyzed independent of each other. For letter description a multiple *t*-test was used only after finding significant differences via an *F*-test.

## RESULTS AND DISCUSSION

**Artificial rainfall experiment**. In total, the soil loss of the 12% slopes was about 78% lower under FC than under CO. For NC, the soil loss was about 29% higher than CO. For the 18% slopes, the soil loss under FC was reduced by 90% and under NC by 78% (data not shown). The runoff ranged between 0.56 L (FC) and 0.86 L for the 12% slopes and between 1.63 L (CO) and 1.73 L (FC) for the 18% slopes (Table 1). Similar results were observed at RS with geotextiles (cotton fibers) also with very low soil loss in plots which were covered with textiles. In contrast to the recent study, the runoff was higher under the covers compared to the non-covered plots (Giménez-Morera et al. 2010). Other studies showed that the infiltration rate is higher and the total soil loss by inter-rill erosion is reduced (Smets et al. 2007) when the soil is covered with straw mulch or agrotextiles. This is reasoned by the restriction of movement by splash, which slows the flow velocity and decreases the runoff-volume (Lattanzi et al. 1974, McGregor et al. 1988).

Table 1. Total soil loss and runoff after three sequences of artificial rainfall (25 mm/h) on 2 slopes with 3 treatments of soil cover in July 2012

| | Slope (%) | | | |
|---|---|---|---|---|
| | 12 | 18 | 12 | 18 |
| | soil loss (g DW) | | runoff (L) | |
| Net cover | 3.93 | 2.73 | 0.71 | 1.67 |
| Fleece cover | 0.68 | 0.95 | 0.56 | 1.73 |
| Control | 3.04 | 9.67 | 0.86 | 1.63 |

DW – dry weight

**Microclimate measurements**. In the FE in 2012, the soil temperature at a depth of 10 cm was on average 1°C higher under FC and 0.5°C higher under NC compared to CO (17.2°C). The soil moisture was highest under FC (27%) followed by NC (26%) and CO (25%; data not shown).

In 2013, the soil temperatures did not significantly differ between the treatments. The soil temperatures ranged between 18.7°C and 18.9°C during the growing period (Figure 1a). These results are contrasting to the study of Wells and Loy (1985), where soil temperatures were highest under row covers. The soil moisture was highest under FC (24%), followed by NC (22%) and CO (21%; Figure 1b). The average daily air temperature, which was measured under the covers, amounted to 20°C under FC, 18°C under NC and 17°C in CO (Figure 1c). The maximum temperature reached 45°C under FC, followed by 37°C under NC and 32°C in CO. Minimum temperature was 7°C under FC and 2°C under NC and CO. High air temperature under row covers was also found in a study in Spain, in Chinese cabbage (*Brassica rapa* L. subsp. *pekinensis* (Lour.) Hanelt) cultivation, with higher air temperature found at the beginning of the cultivation period under FC compared to the non-covered treatment. However, this difference disappeared throughout the growing period (Gimenez et al. 2002). In contrast, in our study, the higher temperature under FC lasted throughout the entire growing period. The average relative humidity varied over time in the recent study in covered plots between 78.4% (NC) and 82.0% (FC; 77.9%). Under CO the relative humidity reached 77.9%. These results are similar to a study by Mermier et al. (1995), who detected higher relative humidity under non-woven fabrics in lettuce cultivation.

**Leaf area index**. At all sampling dates and in both years, LAI was always highest under FC. The LAI ranged in 2012 from 0.03 (CO and NC) on 25$^{th}$ May to 3.87 (FC) on 9$^{th}$ July and in 2013 between 0.27 (CO) and 2.72 during growing season (FC; Table 2). Gimenez et al. (2002) also detected higher LAI under row covers for Chinese cabbage at the beginning of the cultivation period.

**Yield**. During the growing period until the covers were removed, there were always higher DW yields under NC and FC compared to CO (Figure 2a) in 2012.

The DW per plant reached on average from 9 g/plant, 34 DAP to 101 g/plant, 62 DAP.

Average FM head yield under NC and FC was about 80 t/ha, but a significantly lower yield was detected under CO (65 t/ha). The results corroborate with data from garlic (Rekowska and

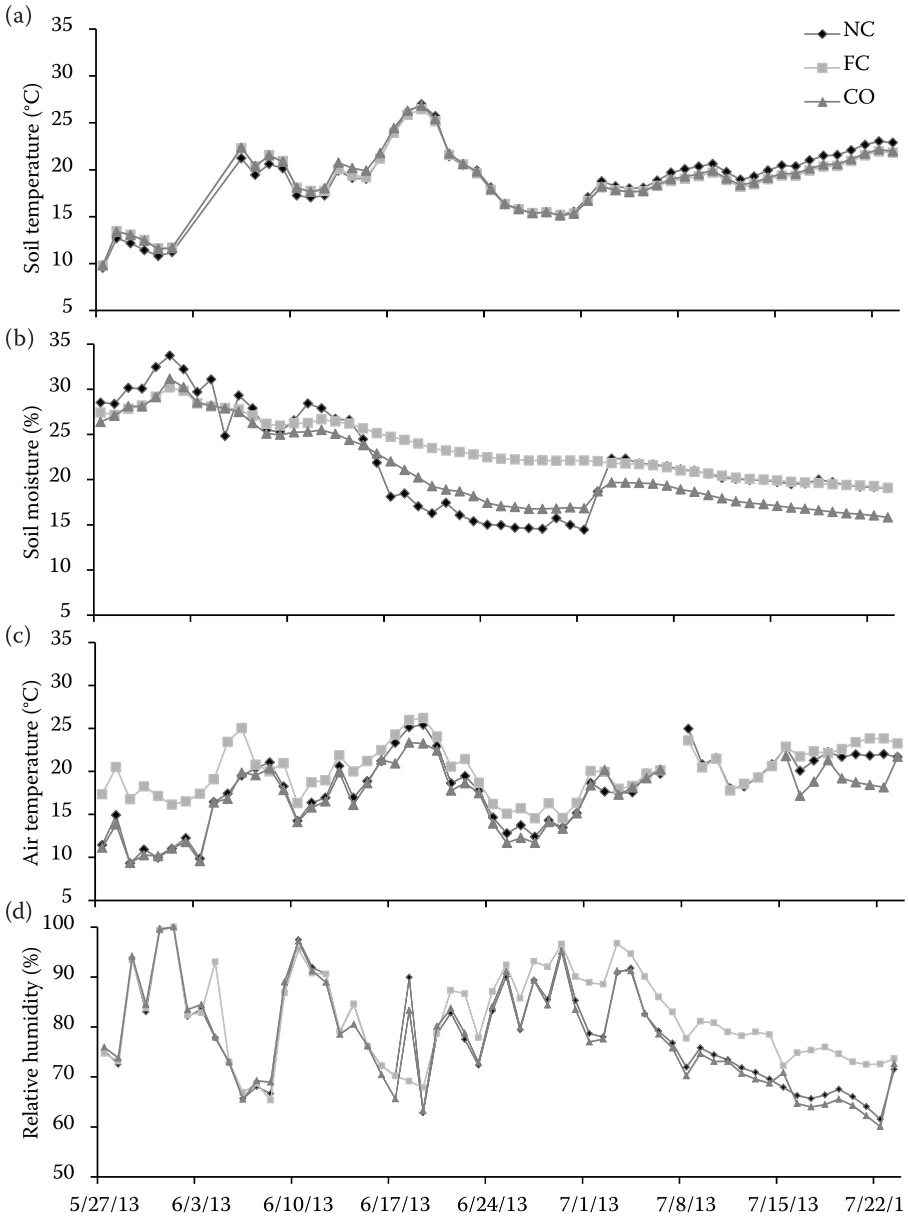


Figure 1. Daily average of soil temperature (a); soil moisture (b); air temperature (c), and relative humidity of air (d) under net cover (NC), fleece cover (FC) and control (CO)

Skupień 2007), shallot (Tendaj and Mysiak 2006), cucumber (Ibarra-Jiménez et al. 2004) and lettuce (Rekika et al. 2009), which were also reported to have higher yields under row covers.

The situation was different in the second experimental year 2013 when cabbage yield (FM) was highest under CO (64 t/ha) and lowest under FC (53 t/ha, Figure 3a). This result was contrasting to most other studies; however, results exist in Chinese cabbage, spinach, beet and lettuce, where the yield was not significantly affected by the row covers (Peacock 1991, Gimenez et al. 2002). The aboveground fresh matter

Table 2. Leaf area index of cabbage leaves in 2012 and 2013

| Treatment | 2012 | | | 2013 | | |
|---|---|---|---|---|---|---|
| | 25.05. | 22.06. | 09.07. | 18.06. | 02.07. | 18.07. |
| Net cover | 0.03[a] | 1.48[a] | 3.48[a] | 0.29[a] | 1.25[b] | 1.95[b] |
| Fleece cover | 0.04[a] | 1.49[a] | 3.87[a] | 0.42[a] | 1.70[a] | 2.72[a] |
| Control | 0.03[a] | 0.84[b] | 2.72[a] | 0.27[a] | 1.24[b] | 2.09[b] |

No significant differences for values with the same letters in column $P < 0.05$

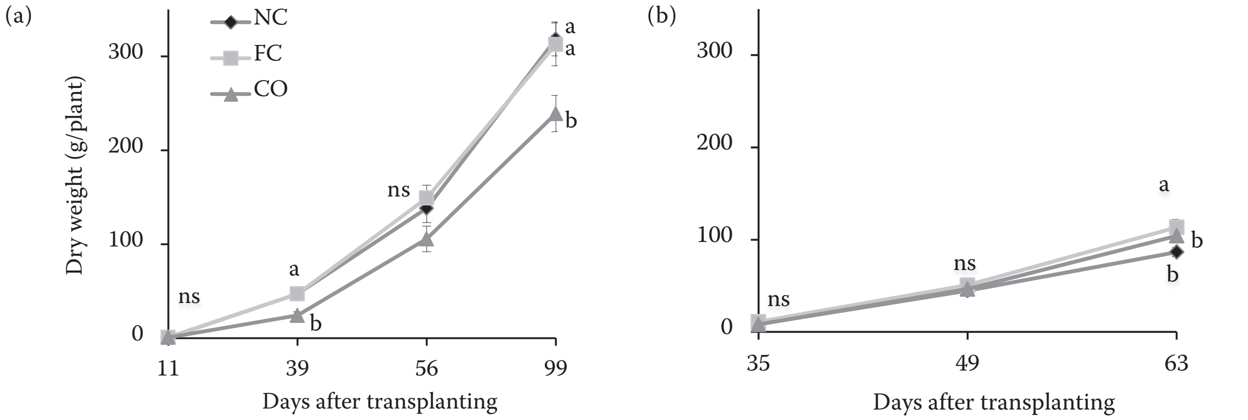


Figure 2. Dry weight of cabbage plants from the different sampling dates in 2012 (a) and 2013 (b). No significant differences for values with the same letters $P < 0.05$. NC – net cover; FC – fleece cover; CO – control

biomass was not significantly different between the treatments in both years (Figure 3b).

The harvest index corresponded to the fresh matter yield. Significantly higher harvest index was recorded under FC (0.58) and NC (0.55) compared to CO (0.48) in 2012. In the second experimental year, a significantly higher harvest index was measured under CO (0.60), compared to the FC (0.54; Figure 4). This indicates that the partitioning (ratio between head and the complete aboveground biomass) of the cabbage plants was not affected by the row covers.

**Diseases and pests**. Row covers by net and fleece can be a physical barrier against cabbage maggot (*Delia radicum* L.) in radish (Rekika et al. 2008) and cauliflower (Millar and Isman 1988) and against flea beetle (*Phyllotreta cruciferae*) in Chinese cabbage (Andersen et al. 2006). In the current study, the infestation with flea beetle in CO (data not shown) might have been the reason for the low yield in 2012. An infestation by cabbage rot (*Sclerotinia sclerotiorum*) occurred under FC where 4% of the cabbage heads were infested compared to 0.5% of the cabbage heads under NC with no infection under CO. No symptoms of *Sclerotinia* rot were visible in 2013. A slightly higher risk of plant diseases under row covers seems to be possible, as also documented for lettuce with a higher infection rate of rib discoloration and tip-burn in lettuce plants under fleece cover (Jenni et al. 2003).

In conclusion, based on this study's findings, the tested row covers seem to be suitable for the control of soil erosion. Also the environmental conditions under the row covers are favored for plant growth; fleece and net can have an additional beneficial effect, regarding higher LAI and similar or higher biomass production under FC and NC. In temperate climate zones, such as Central Europe, and in the case of timely removal of the covers, the risk of plant diseases is predictable.

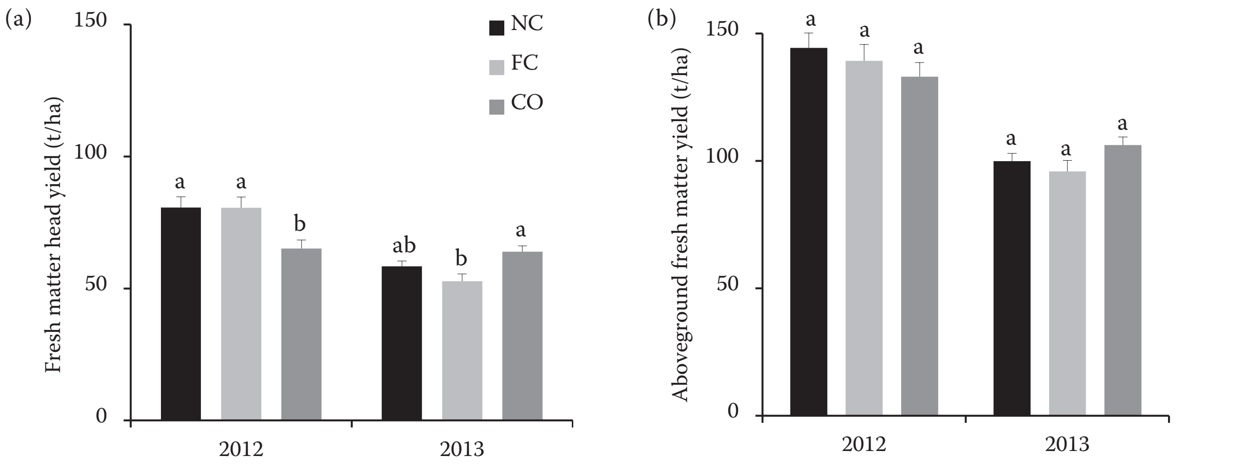


Figure 3. (a) Fresh matter (FM) cabbage head yield and (b) aboveground FM yield in 2012 and 2013. No significant differences for values with the same letters $P < 0.05$. NC – net cover; FC – fleece cover; CO – control

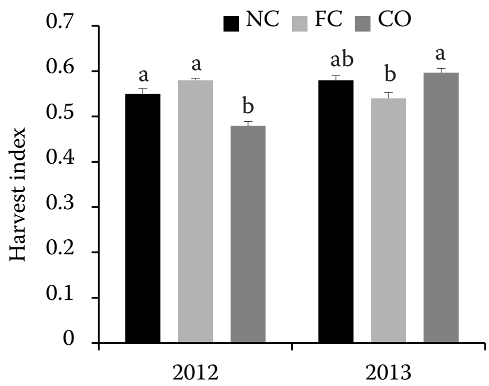


Figure 4. Harvest index of white cabbage in 2012 and 2013. No significant differences for values with the same letters $P < 0.05$. NC – net cover; FC – fleece cover; CO – control

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