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Effects of light, nitrogen and propagative sources on Creeping thistle (*Cirsium arvense* (L.) Scop.)

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Abstract

The concrete frame experiment under field conditions was conducted to determine the effects of light (full light and 85-95% of shade), nitrogen (0 and 100 kg N /ha) and propagative sources (seed and root) on the growth of Creeping thistle. Light was a main factor for Creeping thistle growth. Statistical analysis showed very significant effects of light on plant height, biomass, sprout number, root diameter and survival rate. Constant shade reduced 58.6% of height and 99.5% of biomass. Nitrogen was not a limited factor for early development of individual Creeping thistle, which responded to light more than to nitrogen. The plants grown from seeds were much greater than those from root fragments. The Management of this weed relying on shade would be through using tall crop and shading cropping system.

1 Introduction

Creeping thistle (*Cirsium arvense* (L.) Scop.) is a noxious perennial broad-leaved weed in the Composite family, propagated mainly by horizontal root and by seed. It is one of the world's worst weeds (Holm *et al.,* 1977), exists mainly in Europe, North America and New Zealand, and infests grassland, orchards and non-intensive arable lands. It triggers a special problem in the arable farming systems (Steinmann 1998; Gerowitt & Kirchner, 2000). The relative yield loss ranges from 8 to 70% in wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), oats (*Avena sativa* L.), rape (*Brassica napus* L.) and faba bean (*Vicia faba* L.), depending on its shoot density (Hodgson, 1955; O'Sullivan *et al*., 1982 and 1985; Mclennan *et al*., 1991; Donald & Khan, 1992 and 1996; Kalburtji & Mamolos, 2001). The biology, ecology and management of Creeping thistle were excellently reviewed by Sagar & Rawson (1964), Moore (1975), Holm *et al*. (1977), Donald (1990 and 1994) and Heimann & Cussans (1996).

In all experiments with Creeping thistle, it is very hard to differentiate the effects between nitrogen application and competition for light from the crop. It is not clear whether the growth of aboveground shoots is limited by competition for light or there is a direct effect through the availability of nitrogen to the plant. Very little attention has been paid to the effects of light, nitrogen and propagative sources on its growth. Modelling of the impact of different levels of light and nitrogen on the establishment and early development of Creeping thistle plants propagated from seed (sexual) and from root fragment (asexual) without crop may help forecast the importance of this process. Understanding a response of plant to the environmental factors will permit integration of control methods and result in improved weed management.

2 Materials and Methods

2.1 The conditions of experimental site

The field experiment was conducted at the concrete frames (1 m by 1 m by 1 m, without bottom) of the Research Centre for Agriculture and the Environment, University of Goettingen. The concrete frames were buried in the soil and located in Weendelsbreite of Goettingen, Germany.

The soil type in the concrete frames was a loess-born orthic luvisol with pH ($CaCl_2$) 6.5 – 7.0, sand 3%, silt 85% and clay 12% (Gerowitt & Bodendoerfer, 1998). The soil contained nitrogen (N_{min}) of 34.7-46.8 kg N/ha·90cm·dry soil, phosphate (P-cal) of 9 mg P_2O_5/100g·dry soil and potassium (K-cal) of 11-14 mg K_2O/100g·dry soil. The climatic conditions in Goettingen are of an average annual rainfall 635 mm and an average annual temperature 8.5°C (Teiwes, 1997).

2.2 The experimental treatments and design

The experimental factors and levels were showed in table 1:

Table 1 The factors and levels used in this study.

Factors / Levels	Propagative sources	Nitrogen	Light
1	Seedling (S plant)	0	Shade
2	Root fragment (R plant)	100kg N/ha	Light

The experimental treatments were listed in the following:
(1) Seed and Nitrogen (0) and Shade; (2) Root and Nitrogen (0) and Shade;
(3) Seed and Nitrogen (100) and Shade; (4) Root and Nitrogen (100) and Shade;
(5) Seed and Nitrogen (0) and Light; (6) Root and Nitrogen (0) and Light;
(7) Seed and Nitrogen (100) and Light; (8) Root and Nitrogen (100) and Light.

The trial was laid out as randomised complete block with three replicates.

2.3 Establishment of stands

The seeds of Creeping thistle in this study were collected at Weendelbreite of Goettingen in 1999. For root plants, the seeds were sowed at plastic pots (13 cm by 13 cm, depth 12 cm) in greenhouse in October 1999. The root fragments (1 - 2 cm in length and 3 - 5 mm in diameter) with one sprout (1 - 5 cm in height) were cut from above plants and directly transplanted in the field on May 3, 2000. The same clone roots were used in the same treatment. For seed plants, the seeds were sowed at plastic plate (45 cm by 28 cm, depth 5 cm) in greenhouse (11-37.5 °C) on April 14, 2000. The seed germinated in 10 days after sowing and had 75.8% of germination The seedlings (4 – 4.5 leaves and 2 - 5 cm in height) were transplanted in the field on May 4, 2000.

Six seedlings or root fragments were transplanted in each of the concrete frame. The plants were watered every 2 days for the first week to permit good establishment. The seedlings were replanted in the period of establishment when the plant died but the root fragments were not done because there was no longer the same clone of root fragments and they died less than Seedlings. Slugs were controlled with Metarex® (5% Metaldehyd).

Nitrogen fertilizer with 27% Potassium ammonium nitrate was broadcast on the surface of ground on May 19 (60kg N/ha) and on June 8 (40kg N/ha). It was adopted application of nitrogen (110kg N/ha) in the field of wheat.

The light intensity was simulated on the field of winter wheat growing at different stages and different levels of fertilization. The wheat (Xanthos®) was normally cultivated with 300 seeds/m² (190 kg/ha) in October 1999. The photoactive radiation (PAR, µmol/m² s) in 400-700 nm was determined with LICOR-190-SA light sensor and LICOR L1-1400 data logger. The measurement was carried out in five locations compared to full sunlight at solar noon on a clear day. The average light intensities under wheat were 15% of full light (85% shade) at the elongation stage of wheat (April 26) and 5% of full light (95% shade) at the booting stage of wheat (May 10). Therefore, the plastic shade net (15% transparent) was used from beginning to June 8, then, changed with shade cloth (5% transparent) from June 8 to the end. Net and cloth covered the top and four sides and began 15 cm above the soil surface, then, heightened with the plant growing.

2.4 Data collection

Creeping thistle height (mother plant) was measured in 30, 45, 60, 75 and 90 days after transplanting. The sprout number (new aerial shoots rising from vertical underground stems or from adventitious root buds) was counted at the same time.

Creeping thistle shoots were cut off from the soil surface in 90 days after transplanting. The soil in the concrete frames was excavated to a depth of 50 cm with shovel, and the roots (more than 1 mm in diameter) were collected from the exposed soil profile. Shoot and root fresh weight was weighed immediately after harvesting. Root collar diameter of mother plant was measured with vernier calipers. Dry weight was determined after natural air-dry in greenhouse (about 30 days later).

2.5 Statistical analysis

Data were analysed with general linear model for variables and Scheffe test for the means in the SAS® system (SAS Institute Inc.). Linear regression was used to determine differences among variables of the plants grown under light.

3 Results

3.1 Light on the growth of Creeping thistle

The effect of light was highly significantly different (p<0.01, the some below) on the plant height (Figure 1), sprout number, root collar diameter, survival rate and biomass (Figure 2). The plant height under light (61.1 cm) was 58.6% more than that under shade. The plant biomass under light (41.8 g/plant of total dry weight) was 99.5% more than that under shade. Little biomass was produced under shade.

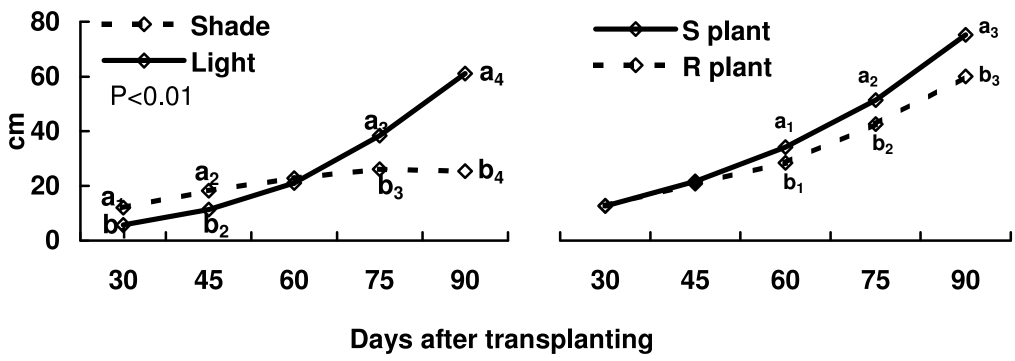

Figure 1 Effects of light and propagative sources on the height of Creeping thistle (Means with the same letter are not significantly different, Similarly hereinafter).

3.2 Nitrogen on the growth of Creeping thistle

The effect of nitrogen was not significantly different on the growth parameter of Creeping thistle, except on root fresh weight (Figure 2).

3.3 Propagative sources on the growth of Creeping thistle

Seed plants of Creeping thistle were highly significantly higher than root plant in 60, 75 and 90 days after transplanting (Figure 1). Seed plant produced biomass highly significantly more than root plant (Figure 2).

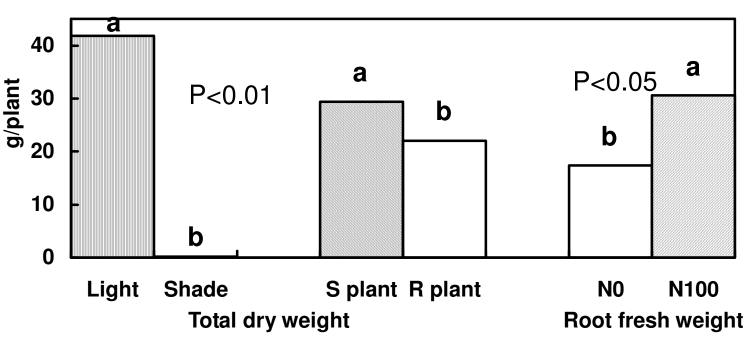

Figure 2 Effects of light, propagative sources and nitrogen on biomass of Creeping thistle.

3.4 Interaction between light, nitrogen and propagative sources

The cross-effect of light and propagative sources was more important than others.

3.5 Relationship

The root diameter of plants under light was highly significantly related to the height (Rd =

0.008 H + 0.24, r^2 = 0.77). Under light condition, the relationship between biomass and height (Total dry weight = 0.86H – 10.6, r^2 = 0.72), or and root diameter (Total dry weight = 84.9Rd – 22.8, r^2 = 0.66) was highly significant.

3.6 The shoot/root ratio and height/weight ratio

The ratio of shoot to root or height to weight was similar in propagative source, nitrogen and under light, but very different under shade (Table). These results fully proved that shading increased plant height, but decreased plant biomass production.

Table 2 The ratios of shoot to root and of height to shoot weight.

Factors	Levels	Shoot/Root (g/g)	Height/Weight (cm/g)
Propagative source	Seed	2.6	2.5
	Root	2.5	2.6
Nitrogen	0	2.6	2.8
	100 kg N/ha	2.5	2.3
Light	Shade	6.7	126.5
	Light	2.6	2.0

4 Discussion

The growth responses of Creeping thistle to light and shade were different. Light increased height growth slowly at the first and then rapidly. Shading benefited the establishment of transplanted seedlings or root fragments and their development up to 60 days. However, Creeping thistle need more light along with the growing. Constant shade reduced biomass production of shoot and root severely.

The results of Creeping thistle response to light in this study support the work by Zimdahl *et al.* (1991). Creeping thistle is shade-tolerant and shade-avoidant. It could survive in low light intensity over 90 days and increase height growth and shoot/root ratio, which might allow the weed to escape shading by the crop and overtop crop. This ability would make control of this species through light manipulation along seem difficult under field conditions. However, Creeping thistle could increase height growth just up to 26 cm and then the height growth tended downwards under shade conditions. Little biomass was produced under shade. The strategy of management of this weed through using tall crop (over 26 cm) and supplying high shade intensity (85 – 95%) by crop before the weed germination would be likely of success. Wheat, rape and alfalfa (*Medicago sativa* L.) are competitive crops with rapid early canopy closure in spring (Donald, 1990) and might have this ability to suppress this weed. The studies of optimizing competition of winter wheat for light have demonstrated great possibilities of weed suppression in organic farming system (Eisele & Koepke, 1997).

Shade-avoidant species (Lambers *et al.*, 1998) can lessen the effects of shade by increasing leaf area in proportion to total plant tissue (Patterson, 1979; Gibson *et al.*, 2001), by increasing photosynthetic rate per unit leaf area (Fischer *et al.*, 2000) and by decreasing energy consumption, i.e. dark respiration (Regnier *et al.*, 1988). However, the role of these mechanisms in the response of Creeping thistle to shade and the knowledge as to how this species recover from shade remains unknown. The morphological and physiological reaction of Creeping thistle to shade would be important to explain its shade-avoidance and management of this weed relying on shade.

Backer (1960) reported the seedlings died when the light intensity fell to 20% of full light. Albeit, in this experiment, there were 56.2% of plants grown from seeds or from root fragments that could survive in 5-15% of full light over 90 days. It was due probably to the difference in experimental conditions.

Nitrogen was not a stress factor for Creeping thistle growth in this study. It increased Creeping thistle plant height, biomass, sprouts and root diameter and decreased survival rate but insignificantly, except for root fresh weight. This was due probably to enough nitrogen in the soil for Creeping thistle growth, or the complete effect of nitrogen fertilization might not be seen in the short duration of the experiment, especially in shade conditions.

The results of Creeping thistle response to nitrogen support the work by Nadeau *et al.* (1990) that indicated nitrogen increased shoot population densities, mostly through increased root growth rather than through released root bud dormancy. The survival rate of Creeping thistle decreasing with nitrogen fertilizer would quote as evidence that nitrogen was harmful to this species (McIntyre & Hunter, 1975), especially under shade condition.

The extent to which management of soil fertility influences Creeping thistle control was complex and depends on crop species, rotation and irrigation system. Fertilizer was applied to enhance crop competitiveness with Creeping thistle, and suggested nitrogen application before the weed germination and after high shade by crop. This would be favourable to crop to form high shade intensity and accelerate the death of the weed. Generally, nitrogen seems to be helpful to control this weed.

In this study, the plants grown from seeds were greater than those from root fragments. It was due probably to the difference in stage of growth of the two types of plants at the time of treatment, the seedlings having 4-4.5 leaves and 2-5 cm in length (establishing easily and growing fast after transplanting), and the root fragments just having one sprout and no new root. The root fragments should be replanted in washed sand in greenhouse after cutting off, then transplanted in the field when they were grown enough as same as seedlings. However, it is difficult to compare seed and root growth under same stage. Both of sexual and asexual reproduction might be important for population biology of this weed in the field. On the contrary, Hamdoun (1970) reported that Creeping thistle plants grown from root fragments (having 5-6 leaves) were greater than those from seeds (having 3.5-4 leaves).

5 Conclusions

Light intensity strongly influenced the growth of Creeping thistle. Little biomass was produced in constant shade. However, The transplanted plants were tolerant to shade at the establishment and early development. This plasticity appears to explain its persistence in the temperate zone.

Nitrogen was not a limited factor for early development of individual Creeping thistle. The plants reacted more to shortage of light than to nitrogen.

Creeping thistle plants grown from seeds were much greater than those from root fragments. The contribution of sexual propagation to the survival of this species should not be underestimated.

The strategy of management of this weed relying on shade would be through using tall crop and shading cropping system. Nitrogen fertilizer would also be helpful to crop by suppressing this weed.

The future research should focus on physiological responses of Creeping thistle to shade and modelling competition of crop and Creeping thistle for light and/or nitrogen.

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