Yield Variability of Organic Winter Oilseed Rape (WOSR) in France: Diagnosis on a Network of Farmers' Fields

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The yields of winter oilseed rape (WOSR) are known to be low and very variable in French organic systems. We aimed to identify the main factors affecting organic WOSR yields. We carried out diagnostic studies on a network of farmers' fields in four contrasting regions of France over 2 years. We assessed, at 4 development stages: weed population and biomass, the nitrogen absorbed by the crop and by weeds and in the soil, and the occurrence of pests and diseases. The crop often suffered from severe nitrogen deficiency in autumn, due to the application of only small amounts of organic manure before sowing and low soil nitrogen content. This deficiency resulted in low biomass and leaf area index (LAI), because WOSR was less competitive against weeds. We found a strong correlation between the intensity of N deficiency in autumn or early spring and weed biomass in late spring: the plots with the highest nitrogen availability in autumn had the highest dry weights and LAI in spring and the lowest relative dry weight for weeds. The yields of these plots exceeded 2.5t/ha, whereas those of the other plots were much lower, due to the combined effects of N deficiency and weed competition. The mean level of insect damage in spring varied from 4% of plants attacked to 63 %, depending on the pest. Spring insect damage rarely exceeded 25%, except for cabbage stem weevil and blossom rape beetle. Few fungal infections were observed.

Key words: winter oilseed rape, organic agriculture, diagnostic, farmers' fields, nitrogen status, weeds.

Introduction

Winter oilseed rape (WOSR) is not widely used in organic agriculture as its yields are low and unpredictable. However, this crop is of potential value in terms of market requirements and agronomic potential. Oil from the seeds could be used in human nutrition: oilseed rape oil is particularly beneficial for human health as it contains omega 3 (Renaud, 1996 and Bourre, 1996). Moreover, oilseed rape cake, corresponding to the solid matter remaining after oil extraction, is a source of low-cost protein that could be used as a supplement to correct the protein deficiencies of cereals (Cetiom, 1998). WOSR is of agronomic value for several reasons. Firstly, the inclusion of WOSR in a crop rotation is known to be of benefit for the following wheat crop (Kirkegaard *et al*., 1994). WOSR also traps nitrate efficiently in autumn (Vos and Vander Putten, 1997; Dejoux *et al*.,1999a). Moreover, Kirkegaard and Sarwar, (1998) and Smith *et al*. (2001) have demonstrated that, as for other brassicas, the glucosinolates present in crop residues have biofumigation potential, which may be effective against take-all (*Gaeumannomyces graminis*).

Despite these potential beneficial effects in cropping systems, oilseed rape is rarely used in organic farming because of its low yield. The major factors limiting WOSR yields are well known in conventional farming (Merrien and Pouzet, 1988; Williams *et a*l., 1991), but have not been clearly identified in organic farming. In this study, we aimed to identify the major factors limiting WOSR yields and the main cultural practices underlying these limiting factors. We used a diagnostic method previously used in other studies (Doré et al., 1997). Our findings have implications for the improvement of cropping systems.

Materials and methods

Experimental design

The network of farmers' fields, in four regions with contrasting climatic conditions, was studied over a two-year period. Farms A to E are located in the centre of France (Auvergne); farms F to K are located in the southern France (Drôme); farms L to M are located near Paris (Eure-et-Loir), and farms O and P are located in eastern France (Bourgogne). We allowed farmers to make their own decisions concerning crop management. Fields were 1 ha to 11 ha in size. To minimise the consequences of this heterogeneity for our measurements, we studied a part of each field (50 m x 100 m minimum) homogeneous in soil depth, texture and crop density.

Measurements and observations
<u>Plants</u>: Plants were sampled at 5 different stages: early winter, (before strong winter drainage and cold temperatures — early November in northern France and early December in the south), late winter, beginning of flowering, pod filling and harvest. On 8 (2001) or 6 (2002) microplots of 0.5m² , we determined the density of plants per m² at each stage, and dry matter and total nitrogen concentration for green aerial parts and tap roots. At harvest, the crop was cut with a combine harvester and yield was estimated from 2 plots of 150m² to 400m². Moisture and individual grain weight were determined for a subsample of approximately 500g. The number of grains per m² was estimated from yield and individual grain weight. Other yield components, such as branching, the number of flowers and the number of fertile pods were analysed on the last date, for a randomly selected subsample of 15 plants.
<u>Soil</u>: Soil and subsoil mineral nitrogen contents were determined by colorimetry after extraction in a solution of 1 N KCl on the same dates as the plants were sampled.
<u>Weeds</u>: On the same dates, we sampled all the weeds present on the microplots. We identified the species present and counted the individuals of each species. The total dry matter of all weeds and the total nitrogen content of the weeds were measured for each sample.
<u>Pests and diseases</u>. Crop damage was estimated on samples of 15 randomly sampled plants per microplot. The main pests observed were: turnip sawfly, rape maggot, cabbage stem flea, aphids, cabbage stem weevil, rape blossom beetle, pod midge and seed weevils. Stem canker damage was estimated on the last sampling date and a score was attributed according to the degree of rot on a collar cut (Aubertot *et al*., 2003).

Results

Yields and yield components
In both years, yield depended more strongly on the number of grains/m^2 than on individual grain weight (data not shown) ($P<0.001$ and $r^2=0.98$). Moreover, in both years, the number of grains was strongly correlated with the amount of nitrogen absorbed in early winter or at the pod formation stage ($P>0.001$; $r^2>0.67$ at pod filling, Fig.1). In some cases, although nitrogen absorption increased during spring, the number of grains reached a plateau: B02, P, M, E01, E'02. Thus, some of the damage occurring in spring may affect yield. Indeed, for field E01, a hail storm 2 days before harvest may account for the decrease in grain number. For E'02 and B, a very strong cabbage stem weevil attack (100% of plants attacked) may have affected the absorption of water and nitrogen. For field P, an attack of rape blossom beetle may have been responsible for low grain number (60% of plants attacked). This attack may have been due to the presence of copses around the field. Thus, in most of cases, the factors affecting yield have their determinant effects during the development of grain number, andnitrogen availability is probably the factor most determinant for grain number.

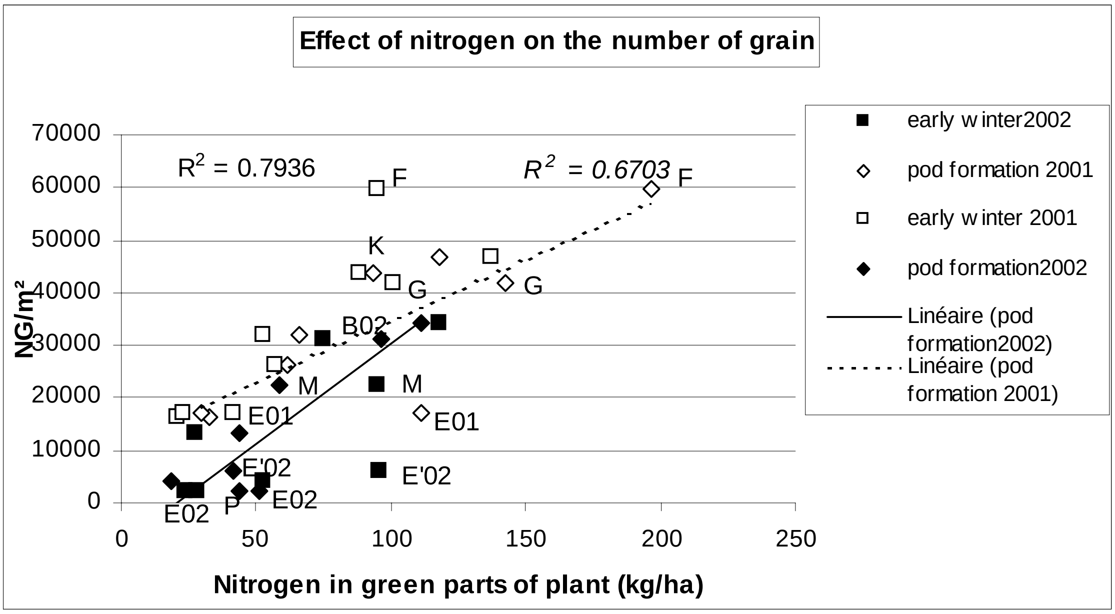


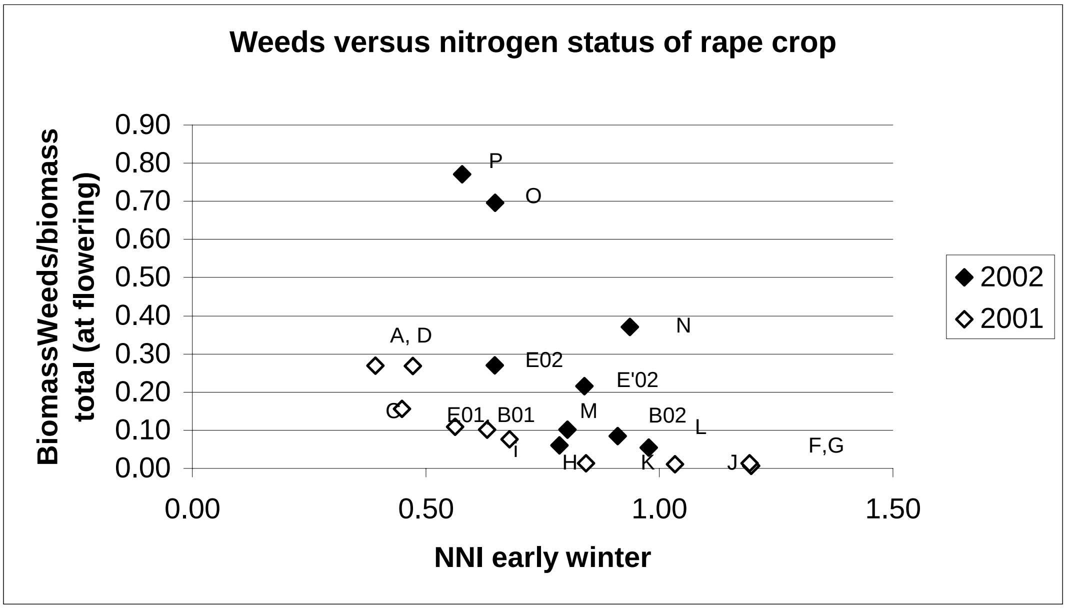
Fig 1: Relationship between plant nitrogen content in early winter or during pod formation and grain number. *R²* indicates linear regression for the first year and normal regression for the second year.

Weeds, pests and diseases
Weed density and biomass were highly variable (from 18 to 544 plants per m²). Weed density tended to increase during autumn and to stabilise after flowering. In 5 of 19 cases, the main weeds in early winter

were volunteers of the preceding crop (wheat or barley). In these cases, competition with volunteers was very strong and continued throughout the rape cropping cycle. Nevertheless, even in the presence of a high density of weeds, the competition ratio in terms of biomass was low and unlikely to decrease yield (fig. 2): fields F, I, K and L. Crop growth, particularly in autumn, seems to smother weeds: figure 2 shows that if nitrogen status in early winter is high, then the proportion of dry weight in weeds is likely to be low. Although the crops of fields N, P and O had a high nutrition status, the proportion of biomass in weeds was high at flowering. The opposite was true for fields M and B02. This may be partly due to the high density of weeds in fields N and O —130 and 85, respectively— and the type of weed — wheat and black grass, which are known to be highly competitive.

There was little damage due to disease: although stem canker (*Leptospheria maculans*) attacked 20% of plants in the first year and 50% in the second year, the disease score did not exceed 2.9 / 9, a very low score, in either year. There were few insect attacks in autumn, whereas some spring pests, such as cabbage stem weevil and rape blossom beetle attacked as many as 63% of plants and 31% of flowers. Aphids were also observed, in particular fielding fields C and I.

Fig 2: Relationship between relative weed dry matter (DM) (DMweeds /(DMweeds+DMcrop)) and nitrogen status of the crop in early winter.



Discussion

The effects of nitrogen deficiency on the LAI and biomass growth of oilseed rape (Asare and Scarisbrick, 1995, Colnenne *et al*., 1999a, 2002), yield components (Colnenne *et al*., 1999b) and photosynthetic activity (Karpen *et al*., 1998) are well documented. In particular, nitrogen determines the number of flowers (Colnenne *et al*., 1999b) and branching (Maillet, 1998). However, it rarely affects the ability of the crop to compete against weeds. Relative weed dry weight has been used to assess weed competition (Lutman *et al*., 2000), but has not been shown to be related to the nitrogen status of the crop. In all but three cases, nitrogen status was related to the capacity of the crop to compete with weeds. Fields F and G gave particularly interesting results: high levels of nitrogen absorption in autumn resulted in high nitrogen status, biomass and LAI of the crop, which smothered weeds, even if present at high density (118 weeds/m²). Other studies have also demonstrated this effect: Ferré (2000) and Dejoux (1999b, 2003) found that high levels of nitrogen absorption were associated with a large increase in biomass and LAI. Our study demonstrated that yield is determined principally by grain number and that nitrogen absorption during the autumn determines the final number of grains. Thus, high levels of nitrogen absorption in the autumn may make the crop more competitive against weeds throughout the crop cycle, by an early smothering effect. The main limiting factors after nitrogen and weeds were two spring insects: cabbage stem weevil and rape blossom beetle. The fields that experienced the most severe pest attacks had numerous refuge zones, such as trees, copses and bushes. It suggests that surrounding environment was correlated with crop damage for these pests, as previously shown for slugs by Franck, 1998. Thus, it should be possible to increase WOSR yields in organic systems by ensuring that nitrogen availability is high at sowing and during the autumn. Mixed farms and farms with other sources of organic manure could easily adopt this crop in as part of their rotation.

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