Effects of pod position and its appearance time on pod and seed abortion in winter oilseed rape (*Brassica napus* L.)

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Introduction

Yield of winter oilseed rape (WOSR) is determined, in large part, by the number of pods and the number of seeds per pod. Flowers differ in their number of ovules, hence pods differ in their number of seeds within one inflorescence (Wang et al., 2009). Flowering and pod set is a dynamic system. Time plays a role in determining pod and seed number at maturity. On a given inflorescence or individual, the basal fruits have a spatial advantage as well as a temporal one (Stephenson, 1981). The flowers appear and develop earlier than the distal flowers. The early developed fruits and seeds receive more resources than the later ones (Thomson, 1989). Alternatively, flowers and seeds located close to the source of assimilate have more chance to survive (Diggle, 1995). Determining the sources of yield variation is crucial to improve the pod and seed production in WOSR. As flowers are produced at different times or at different positions, thus they may be subjected to varying levels of competition for assimilates. Furthermore, the flowers develop at different positions along the inflorescence and the plant axes (Diggle and Miller, 2004). The variation of pods and seeds could be also due to architectural effect (Diggle, 1995). In addition, insufficient pollination also can lead to the failure of pod and seed production. As WOSR plant development is sequential, the location of a flower in the plant determines its time of appearance. On a stem, flowers develop acropetally along the inflorescence. The inflorescences initiate acropetally but expand basipetally. The main stem develops first followed by the lateral inflorescences (Tittonel, 1990). Flowers at the distal positions on the main stem usually open after those at the basal positions on the lower inflorescences. In addition, pods from the first flowers at upper inflorescence may already be large sinks (more chances to obtain assimilates) with the seeds in the linear phase of growth when the first flowers at a lower inflorescence opens. Late developing flowers and pods have higher rates of reproductive failure than early developing ones (Thomson, 1989). The late developing pods would probably abort within one inflorescence, but would they abort if they were at different inflorescences? The asynchronous flower and pod production results in the pods at different stages of development within one inflorescence and between inflorescences. Thus, we need to study if the number of seeds and pods of the distal pods developed at the same time but located at different inflorescences differ. The study of pod and seed abortion requires consideration of the time of pod development and its position in the plant. The aim of this study is to investigate how the position and appearance time of pods impact the abortion of pods and seeds on the main stem and ramifications.

Materials and methods

Field experiments were conducted in Grignon at the National Institute for Agricultural Research (INRA). The variety is Mendel. The plants started to flower in mid-April, and the flowering season continued until mid-May. 18 plants were randomly marked in mid-April, just before the flowering season. When the plants began to bloom, the positions and the times of appearance of pods were recorded every two to three days throughout the flowering season from the main stem (R0) and from the ramifications (R1, R4, R7, R9 and R11) numbered from top to bottom. The number of seeds and aborted seeds per pod was counted when the pods stop to develop. The number of ovules per pod was calculated as the sum of undeveloped ovules, aborted seeds and mature seeds per pod.

All statistical computations were conducted using R 2.11.1 (Copyright (C) 2010 the R Foundation for Statistical Computing). Three positions on the stem were selected by gathering the pods ten by ten to analyse the effect of pod position and time of appearance. Because the length of inflorescences is different between plants, pod ranks were normalised for each inflorescence by dividing the pod rank by the maximum rank on the inflorescence. This approach allows the conversion of the ranks of all of the inflorescences into a range between 0 and 1. Analysis of variance (ANOVA) was performed to test the effect of ramification position on the number of ovules per pod, seeds per pod, total pods per axis and seeds per axis.

Results

Number of ovules per pod

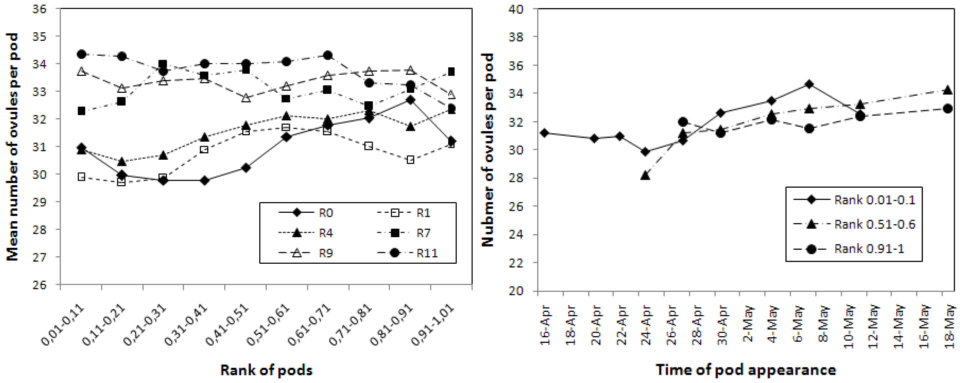

Fig.1 (a) Mean number of ovules per pod according to pod rank for each inflorescence. (b) Mean number of ovules per pod for low, middle and high pods according to the time of appearance.

The number of ovules per pod varied with the pod rank on the main stem and ramifications R1 and R4 (Fig. 1a). The number was small at the first ranks and then increased with the pod rank. The number of ovules per pod remained constant according to the pod rank on ramifications R7, R9 and R11 (Fig. 1a). Furthermore, the number of ovules per pod increased with the inflorescence position from top to bottom. The number of ovules per pod slightly increased with the time of pod appearance for normalized rank 0.01-01, 0.51-0.6 at the beginning and then remained constant for all the ranks on each inflorescence (ANOVA, F>0.5, P>0.1, Fig. 1b).

Number of seeds per pod

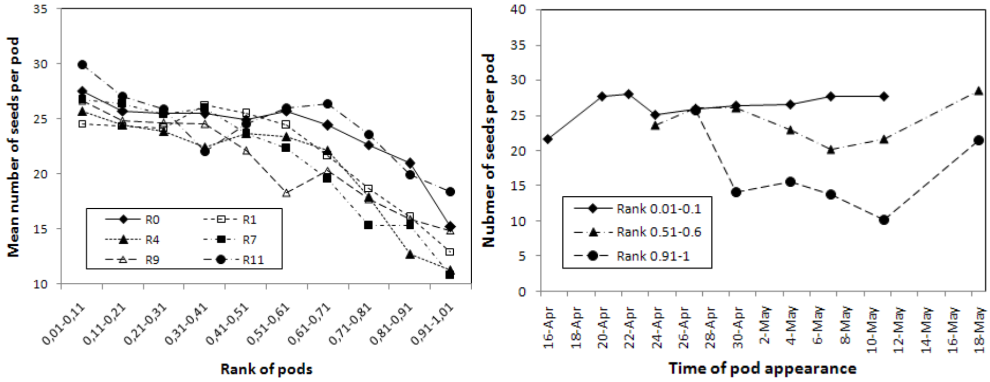

Fig.2 (a) Mean number of seeds per pod according to pod rank for each inflorescence. (b) Mean number of seeds per pod for low, middle and high pods according to the time of appearance.

The number of seeds per pod remained constant then decreased with the pod rank along the inflorescence (Fig. 2a). The number of seeds per pod decreased later on the main stem and ramification R11 than the other ramifications. The number of seeds per pod did not vary with the time of pod appearance for normalized rank 0.01-01, 0.51-0.6 by gathering all the inflorescence together (ANOVA, F>0.5, P>0.1). However, the number varied with time of pod appearance for normalized rank 0.91-1. Furthermore, the number differed between rank 0.01-0.1, 0.51-0.6 and 0.91-1 (Fig. 2b). The pods located at rank 0.91-1 had smaller number of seeds per pod.

Number of pods

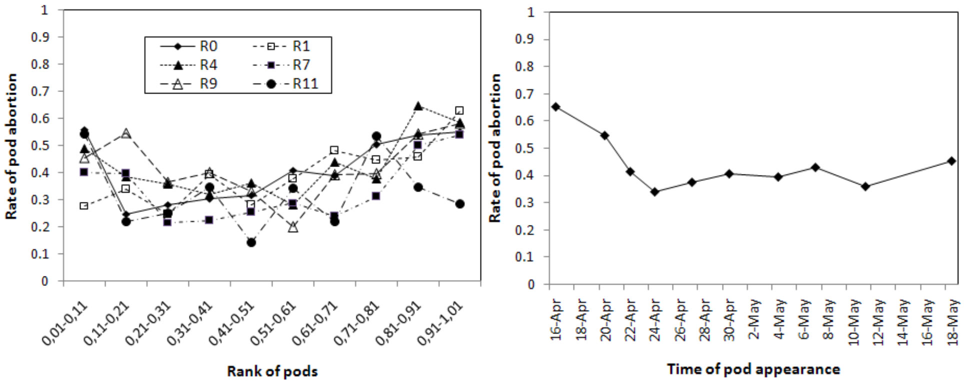

Fig.3 Variation of rate of pod abortion with pod rank (a) and according to the time of pod appearance (b).

The rate of pod abortion was a little large at the base and remained constant in the middle of the stem, and then increased linearly with the rank upwards on each ramification (Fig. 3). It did vary in the beginning, but decreased at the end of flowering period. The inflorescence position had no impact on this rate (ANOVA, P>0.1) for the basal pods.

Discussion

The number of ovules per pod increased with the rank on the main stem and ramifications R1 and R4, but it did not vary with the rank on ramifications R7, R9 and R11. However, the number increased with the inflorescences. Ramifications are initiated from bottom to top, but the expansion of ramifications is in the inverse order of their initiation and is delayed compared with the main stem. The duration between initiation and expansion is longer for basal ramifications than for upper ramifications. Thus, initiated pods on the basal ramifications have a longer developmental period, which could explain the greater number of ovules per pod in the lower ramifications. The number of seeds per pod decreased with the pod rank for each inflorescence. The variation of the number of seeds per pod could due to assimilate availability. The flowers open acropetally within one inflorescence, thus, the basal pods developed earlier and had more chance to obtain assimilates than the distal pods. Furthermore, the time of pod appearance could impact the number of seeds per pod on the plant level. The distal pods have less number of seeds per pod compared to the basal pods that appeared at the same date. The rate of pod abortion was large at the beginning and the end of the stem, which could be caused by pollination limitation. The number of flowers was small at the beginning and increased with the time of flowering, and then reduced at the end of flowering. The number of seeds starts to increase when the pod abortion rate starts to decrease. The result indicates that the survival of pods depends on the number of seeds it contains (Ganeshaiah et al., 1986). The complex developmental pattern of flowers and inflorescences in WOSR makes the analyses for the factors of influencing seed yield difficult. Therefore, to improve the seed yield, more concentration could be focused on the developmental patterns of WOSR.

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