Seed yield and yield components of red clover (Trifolium pratense L.) genotypes

Vladeta STEVOVIĆ, Dalibor TOMIĆ, Dragan ĐUROVIĆ
University of Kragujevac, Faculty of Agronomy in Čačak, Cara Dušana 34, 32000 Čačak, Serbia, (e-mail: dalibor@tfc.kg.ac.rs)

Abstract
The objective of this study was to evaluate seed yield and yield components (stem number per plant, inflorescence number per stem, inflorescence number per plant, flower number per inflorescence, seed number per inflorescence and seed fertility) in individual plants of ten genotypes of red clover grown at low plant density (70 x 40 cm) in order to single out genotypes that have a higher seed yield potential. Significant differences among genotypes were determined for flower number per inflorescence, seed number per inflorescence, flower fertility and seed yield. The results obtained suggest that certain genotypes may be used for further selection work.

Key words: red clover, genotypes, seed yield, seed yield components

Introduction
Seed yield of red clover (Trifolium pratense L.) is mostly dependent upon the genetic background of cultivar, environmental conditions, first cut date, presence of insect pollinators, and genotype/environment interaction (Steiner et al., 1995). The high variability and genetic plasticity of the species are the result of the extremely xenogamous character of fertilisation and entomophilous pollination (Taylor and Smith, 1979). The high variability and adaptability to diverse environmental conditions have contributed to the development, through natural selection, of a large number of local ecotypes that show superiority under particular growing conditions (Helgadottir, 1996).

Given the high genetic potential for biomass yield in the species herewith studied, selection work should involve monitoring of major traits of seed yield and yield components. Improvement of the seed yield production potential is rarely seen as an important criterion during the early stages of red clover selection. Breeding for increased seed yield potential has also been further hampered by the absence of clearly defined interrelation between seed yield and yield components. However, the significant genotype-specific correlation between harvest index and seed yield suggests the possibility of an increase in seed yield without any adverse effects on forage yield (Elgersma and Van Wijk, 1997).

The objective of this study was to analyse seed yield and yield components in red clover genotypes in order to select genotypes that have higher seed yield potential. The genotypes would serve as a good basis for further hybridisation and development of cultivars that would exhibit higher seed yield, apart from higher forage yield potential.

Materials and methods
This experiment was set up on 4 June 2009 as an on-field trial at the Veterinary Extension Service in Čačak (43°54'39.06" N, 20°19'10.21" E, 246 m a.s.l.) on alluvial soil acid in reaction (pH$_{H_2O}$ 4.8), poor in nutrients and low in organic matter. Primary tillage was coupled with incorporation of 300 kg ha$^{-1}$ N$_{15}$P$_{15}$K$_{15}$ into the soil. The factorial trial was established as a completely randomised block design in five replications with 20 plants per 4x1.4 m plot. Plants were grown under low density at a spacing of 70x40 cm. A total of ten red clover genotypes, including nine diploid genotypes (G1, G2, G4, G8, G9 and G10 selected from cvs. Viola, Una, Kolubara, Avala, K-17 and K-39, respectively, and G3, G6 and G7 selected from local populations found...
in the vicinity of Čačak) and the tetraploid genotype G5 selected from cv. K-27 Tetra, were used in the study. The second cut of the second year of cultivation was analysed for seed yield and yield components. Mechanical weed control was employed on a number of occasions. No irrigation was employed.

Mean air temperatures during the 2009 growing season (April through September) were 1.33°C above the ten-year average, whereas total rainfall was 351 m² below average.

The second cut of the second year of cultivation was analysed for seed yield and yield components. Mechanical weed control was employed on a number of occasions. No irrigation was employed.

Mean air temperatures during the 2009 growing season (April through September) were 1.33°C above the ten-year average, whereas total rainfall was 351 m² below average.

The seed yield components undergoing an on-field analysis included the following: stem number per plant, inflorescence number per stem, and inflorescence number per plant. The components were counted on five plants randomly selected from the plot. Laboratory analyses involved determination of flower number per inflorescence and seed number per inflorescence (on a sample of ten inflorescences randomly selected from individual plants), fertility (number of fertile flowers during seed maturation stage based on the relationship between seed number and flower number per inflorescence) and thousand seed weight (using 5x100 seed weight). The actual seed yield was determined from yield components (inflorescence number per plant, seed number per inflorescence, thousand seed weight) and calculated for seed yield given as g/plant.

The results on seed yield and yield components were subjected to a single-factor analysis of variance (SPSS, 1995). The significance of differences between mean values was tested by the LSD test. The correlation between seed yield and yield components was evaluated by calculating the simple correlation coefficient based on ten measurements of flower number per inflorescence, seed number per inflorescence, and fertility i.e. five measurements of stem number per plant, inflorescence number per both stem and plant, and seed yield per plant.

**Results and discussion**

No significant differences in stem number per plant and inflorescence number per stem were observed in the genotypes tested (Tab. 1). The average stem number per plant was 23, ranging from 19 (G1) to 29.2 (G2). The average number of inflorescences per stem was 3.95, being within a range of 2.9 (G3) to 4.7 (G2). As reported by Vasiljević et al. (2010), the average number of inflorescences per stem in cv. Una was 6.7 under row spacing of 40 cm and seed rate of 2.1 kg ha⁻¹. The lower inflorescence number per stem in the present study was most likely associated with low soil pH i.e. lower nutrient availability.

The average number of inflorescences per plant was 85.8. A significantly higher number was found in G2 than in G3, G4, G9, G10. Montardo et al. (2003) suggests that inflorescence number per plant is among major yield components that should be given due attention in red clover selection for higher seed yields.

Flower number per inflorescence was substantially higher in G3 (100.0) than in other genotypes excepting G1(93.3) and G10 (88.0). Oliva et et al. (1994) report an average flower number per inflorescence in cv. Kenland to range from 101 to 142. Julen (1956) and Miladinović (1978) found large differences in flower number per inflorescence among red clover genotypes.

Genotypes G1 and G10 gave a significantly higher seed number per inflorescence (57.8 and 56.7) as compared to the other genotypes, excepting G3 (52.5). Seed number per inflorescence was substantially lower in G5, which was an expected result, given its being a tetraploid. Đukić et al. (2010) produced an average of 105.9 seeds per inflorescence in cv. Una at a row spacing of 60 cm. Wilczek and Ćwintal (2008) report the range of 61 to 74 for seed number per inflorescence in cv. Parada. Additionally, the same authors underline that seed number per inflorescence and flower fertility are the most important seed yield components of red clover. Jevtić et al. (2007) and Wilczek and Ćwintal (2008) also suggest the strong effect of insect pollinators on seed number per inflorescence. The lower seed number per inflorescence and decreased fertility in the present study were most likely due to the high rainfall amounts during the pollination season.

The average flower fertility for the genotypes was 50.8%. Fertility was significantly higher in G8 (68.8%), G10 (64.4%), G1 (63.3%) and G2 (63.4%) as compared to G4, G6 and G5 (Tab. 1). Oliva et al. (1994) report flower fertility in red clover cultivars to range from 76 to 99%. Wilczek and Ćwintal (2008) observed fertility variations of 51.2-69.8% across years, suggesting that high rainfall amounts during flowering may substantially reduce fertility and harvest index as compared to the potential seed yield.

The average seed yield per plant was 5.1 g. Seed yield was substantially higher in G10 (8.0 g), G2 (7.9 g) and G1 (7.3 g) than in G4 and G5 (Tab. 1). The lowest seed yield was obtained with G5, being in agreement with the results of Vojin (2007) who suggested significantly higher seed yield in diploid genotypes than in
Seed yield and yield components of red clover (Trifolium pratense L.) genotypes
tetraploid cultivars. Herrmann et al. (2006) report that the average seed yield per plant in two red clover genotypes was 5.72 g, with the range being 0.71-11.31 g.

Table 1. Mean seed yield and yield components of red clover genotypes: stem number per plant-SNP, inflorescence number per stem-INS, inflorescence number per plant-INP, flower number per inflorescence-FPI, seed number per inflorescence-SNI, flower fertility-F (%), and seed yield-SY (g per plant).

<table>
<thead>
<tr>
<th>Genotype</th>
<th>SNP</th>
<th>INS</th>
<th>INP</th>
<th>FPI</th>
<th>SNI</th>
<th>F</th>
<th>SY</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>19.0</td>
<td>4.2</td>
<td>82.4ab</td>
<td>91.3ab</td>
<td>57.8a</td>
<td>63.3ab</td>
<td>7.3a</td>
</tr>
<tr>
<td>G2</td>
<td>29.2</td>
<td>4.7</td>
<td>130.2a</td>
<td>67.0d</td>
<td>42.5bcd</td>
<td>63.4ab</td>
<td>7.9a</td>
</tr>
<tr>
<td>G3</td>
<td>27.8</td>
<td>2.9</td>
<td>76.8b</td>
<td>100.0a</td>
<td>52.5ab</td>
<td>52.5bc</td>
<td>6.9ab</td>
</tr>
<tr>
<td>G4</td>
<td>24.7</td>
<td>4.0</td>
<td>80.2b</td>
<td>72.9bcd</td>
<td>33.5de</td>
<td>45.9c</td>
<td>2.9bc</td>
</tr>
<tr>
<td>G5</td>
<td>22.6</td>
<td>4.5</td>
<td>97.6ab</td>
<td>60.6d</td>
<td>2.1f</td>
<td>3.5d</td>
<td>0.4c</td>
</tr>
<tr>
<td>G6</td>
<td>23.6</td>
<td>3.6</td>
<td>86.2ab</td>
<td>68.6cd</td>
<td>30.8e</td>
<td>44.9c</td>
<td>4.0abc</td>
</tr>
<tr>
<td>G7</td>
<td>21.0</td>
<td>4.1</td>
<td>83.8ab</td>
<td>69.4cd</td>
<td>35.7cde</td>
<td>51.4bc</td>
<td>4.0abc</td>
</tr>
<tr>
<td>G8</td>
<td>21.2</td>
<td>4.2</td>
<td>85.0ab</td>
<td>65.4d</td>
<td>45.0bc</td>
<td>68.8a</td>
<td>5.6ab</td>
</tr>
<tr>
<td>G9</td>
<td>19.6</td>
<td>3.4</td>
<td>61.4b</td>
<td>76.7bcd</td>
<td>39.1cde</td>
<td>50.1bc</td>
<td>4.5ab</td>
</tr>
<tr>
<td>G10</td>
<td>21.2</td>
<td>3.9</td>
<td>74.2b</td>
<td>88.0abc</td>
<td>56.7a</td>
<td>64.4ab</td>
<td>8.0a</td>
</tr>
<tr>
<td>$\bar{x}$</td>
<td>23.0</td>
<td>3.9</td>
<td>85.8</td>
<td>76.0</td>
<td>39.6</td>
<td>50.8</td>
<td>5.1</td>
</tr>
</tbody>
</table>

ANOVA ns ns ns ** ** ** **

The values denoted with different small letters within columns are significantly different at (P<0.05) in accordance with the LSD test; **-F test significant at p<0.01; ns-F test non-significant.

Table 2. Coefficients of correlation among stem number per plant (SNP), inflorescence number per stem (INS), inflorescence number per plant (INP) and seed yield per plant (PS).

<table>
<thead>
<tr>
<th></th>
<th>INS</th>
<th>INP</th>
<th>PS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNP</td>
<td>-0.27</td>
<td>0.32*</td>
<td>0.23</td>
</tr>
<tr>
<td>INS</td>
<td>-</td>
<td>0.46*</td>
<td>0.16</td>
</tr>
<tr>
<td>INP</td>
<td>-</td>
<td>-</td>
<td>0.57*</td>
</tr>
</tbody>
</table>

* Significant at p<0.05

Table 3. Coefficients of correlation between seed number per inflorescence (SNI), flower number per inflorescence (FPI) and flower fertility (F) (%).

<table>
<thead>
<tr>
<th></th>
<th>SNI</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>FPI</td>
<td>0.82*</td>
<td>-0.30*</td>
</tr>
<tr>
<td>SNI</td>
<td>-</td>
<td>0.22*</td>
</tr>
</tbody>
</table>

* Significant at p<0.05

Inflorescence number per plant was positively correlated with stem number per plant and inflorescence number per stem (Tab. 2). Additionally, a significant positive correlation was observed between inflorescence number per plant and seed yield per plant. The results obtained are in agreement with those reported by Montardo et al. (2003) and Herrmann et al. (2006). Moreover, Herrmann et al. (2006) emphasise that inflorescence number per plant is a primary component determining seed yield.

Flower number per inflorescence was positively correlated with seed number per inflorescence and negatively correlated with flower fertility (Tab. 3). A positive correlation was also observed between seed number per inflorescence and flower fertility. Herrmann et al. (2006) reported a positive correlation between seed yield per plant and seed number per plant, seed yield per plant and flower fertility, and seed number per inflorescence and flower fertility.

Vasiljević et al. (2000) observed that coefficients of genetic correlation showed that seed yield per plant was mostly dependent upon seed yield per inflorescence, flower number per inflorescence and number of productive stems per plant. The authors also suggest significant positive genetic correlations between inflorescence number and internode number per stem i.e. green material yield, as confirmed by Steiner and Alderman (2003). Identical findings were reported by Ianucci and Martinello (1998) in their study on three Mediterranean clover populations. The obtained results suggest justifiability of selection for both forage and seed yield.

Conclusion

The test genotypes showed substantial differences in inflorescence number per plant, flower number per inflorescence, seed number per plant, seed fertility and seed yield per plant.

G1, G2 and G10 stood out in terms of seed yield and yield components.
The calculated values of correlation coefficients suggest that the highest effect on yield per plant was produced by number of inflorescences per plant and, indirectly, by flower number per inflorescence. Further selection should be focused on increasing values of the said traits.

Irrespective of stem number per plant, inflorescence number per stem, inflorescence number per plant and flower number per inflorescence, the tetraploid genotype G5 had very low flower fertility, being reflected in seed number per inflorescence and total seed yield per plant.

References


sa2011_0324