The Evaluation of Yield and Agronomic Traits of Flax Genotypes Under Latvian Conditions

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Abstract—This study aim was evaluated of flax genotypes regarding productivity, resistance to lodging and diseases as well as yield dependence relationships among phenotypic and quality traits. The 14 fibre flax genotypes were evaluated in field conditions on the background of natural infection from 2014 to 2018 for agronomically important traits and from 2015 to 2018 for occurrence diseases of flax. The data were recorded for the 15 following agronomic traits, such as flowering time, plant height, plant branching, and days to early yellow ripening stage played a major role on stem yield as well vessels per plant and harvest index on seed yield. The flax genotypes ‘Vilani’, ‘L26-1’, ‘K9-1’, ‘T36-1’, ‘S37-1’ exhibited significant highest stem yield ranging from 643.20 to 693.32 g m⁻² and technical length ranging from 65.90 to 70.58 cm comparing to standard variety ‘Vega 2’. The most perspective genotype of ‘Vilani’ with quit low susceptibility to anthracnose, pasmo and powdery mildew and resistance to lodging was identified.

Key words—agronomic traits, correlations coefficient, diseases, fibre flax, yield

I. Introduction

Flax a multipurpose crop cultivated for fibre and seeds. Many investigators indicated that flax genotypes significantly differed in their growth habits and their response to cultural practices as well as production of fibre and oil, of them [1] – [4]. Similar like in the Latvia, in the Europe the aims of new flax varieties are: resistance to lodging reaching 9 points of the grade, middle early vegetation period, yield potential of stem reaching 7 – 8 t ha⁻¹, yielding potential of the seeds reaching 1.10 – 1.30 t ha⁻¹ in the trials [5]. Yield is the most important and complex trait in crops that show correlations with other traits [6]. Being a polygenic trait it is greatly influenced by environmental fluctuations. To obtain superior varieties with high yielding potential, the plant breeder has to deal with characters, which are governed by polygenic systems and show continuous variation [7]. Other important agronomic traits such as flowering time, plant height, plant branching, and lodging resistance may also indirectly affect yield through various physiological mechanisms [6], [8], allowing crop phenology and plant architecture to be adapted to regional growing conditions, thus avoiding yield and quality losses [9]. Knowledge of association between yield and its attributes obtainable through estimation of genotypic and phenotypic correlation helps to formulate plant breeding strategies to develop suitable genotypes [10], [11]. The positive correlation between major yield components, breeding strategies would be very effective but on the reverse, selection becomes very difficult [12].

Flax yield and profitability can be greatly affected by diseases occurrences. Pasmo, anthracnose, powdery mildew are fungal diseases of flax and attacking all aboveground parts of the plant. These diseases can reduce the yield and quality of seed and fiber raw materials, with most losses resulting from premature ripening and loss of seed during harvest, although reductions in seed number per plant can occur with early infection [13] – [15].

In recent years, it has become more difficult to breed new fibre flax varieties with a better fibre quality, increased fibre yield, and the required resistance, due to repeated use of modern cultivars as crossing parents [5]. Therefore, the aim of this study was evaluated of flax genotypes regarding productivity, resistance to lodging and diseases as well as yield dependence relationships among phenotypic and quality traits.

II. Materials and Methods

A. Field Trials

The research was conducted at the Institute of Agricultural Resources and Economics, Research Centre of Priekuli, research unit Vilani since 2014 to 2018 for agronomically important traits of flax and since 2015 to 2018 for occurrence of fungal diseases during early yel-
low ripening stage. Experimental material for the study consisted of 13 fibre flax genotypes of the Latvian origin (‘Table 1’) and ‘Vega 2’ (ST) as the standard variety of Lithuanian origin. Since 2017 the variety ‘Vilani’ (breeding line (‘I18-1’)) has been tested successfully for DUS and for VCU is still on the way.

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Genotype</th>
<th>Nr.</th>
<th>Genotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>S29-1</td>
<td>8.</td>
<td>K9-1</td>
</tr>
<tr>
<td>3.</td>
<td>S37-1</td>
<td>10.</td>
<td>L26-1</td>
</tr>
<tr>
<td>4.</td>
<td>S37-2</td>
<td>11.</td>
<td>I7-1</td>
</tr>
<tr>
<td>5.</td>
<td>T36-1</td>
<td>12.</td>
<td>I7-2</td>
</tr>
<tr>
<td>6.</td>
<td>T36-2</td>
<td>13.</td>
<td>Vilani (I18-1)</td>
</tr>
<tr>
<td>7.</td>
<td>T36-3</td>
<td></td>
<td>ST Vega 2</td>
</tr>
</tbody>
</table>

The experiment was set up in randomized block design in three replicates at 2 m² with a distance between rows 10 cm. Flax was grown in Humic Gleyic Podzols (PZ-gl-hu) soil [16]. The main agrochemical parameters of the arable soil layer were following: humus content – 6.5%, soil acidity (pH_{KCl}) – 6.4–7.0, available P_{2}O_{5} = 130–145 mg kg⁻¹ and available K_{2}O – 118–124 mg kg⁻¹ soil. Complex fertilizer NPK 16:16:16 – 300 kg ha⁻¹ was applied after first soil cultivation. 1700 flax seeds per 1 m² were sown by hand with sowing depth 1.5–2 cm at the field trial. Prior to sowing, germination tests were performed for all used genotypes. Seeds were sown during the first 10 days of May. For plants’ further development a surface fertilizer - ammonium nitrate 30 kg ha⁻¹ N in fir-tree like phase was applied. Insecticides (Fastac 50 0.4 L ha⁻¹, a.s. 50.0 g L⁻¹ alpha-cypermethrin) were sprayed against flax flea beetles (Aphthona euphorbiae) as required by the instructions. The tractor-drawn sprayer “Pilmet 412” was used for insecticide application. Fungicides for flax diseases were not used at all. Plants were pulled manually at the stage of early yellow ripeness and then left on ground for air-drying for 5–8 days. The seed-vessels were removed by “Eddi” device. Seeds were cleaned with sample cleaner MLN (Pfeuffer GmbH, Germany). The yield of seeds was weighed and then re-calculated to weight by 100% purity and 12% humidity. Seed oil content was determined on grain quality analyzer “Infratec 1241” (FOSS, Denmark). The total and technical plant heights, fibre content were determined using randomly selected most typical 20 plants in each parcel area before the harvest. The yields of stem and seed were determined in each harvested parcel area. The resistance of plants to lodging, length of growth stages of flax were evaluated [17]. The harvest index (HI) was calculated in percentage as the ratio of seed yield to plant weight after plant maturity [10].

Thirty flax plants from each genotype at the 2 m² in the field trials were assessed during early yellow ripening stage under field conditions with natural infection background. The analyses of infected parts of the plants were done following the methodologies developed for phytopathological research [18]. The diseases were determined by morphological features were using disease descriptors [18], [19]. Percentage of the affected plants was estimated and disease severity was recorded for the whole plant for each disease following a five-point scale: 0 – healthy, 1 – weakly affected, 2 – moderately affected, 3 – heavily affected, 4 – very heavily affected or dead plants. Disease severity index “(1)” was calculated by applying formula [18]:

\[
DSI = \frac{\sum(ab) \times 100}{A \times S},
\]

where DSI is disease severity index, %, a – number of infected plants, b – degree of infection used five-point scale, A – total number of plant samples (healthy and infected), S – the highest degree of infection.

B. Meteorological Conditions

Agro-meteorological conditions were determined by ADCON installed meteorological stations connected to the computer program Dacom Plant Plus. The facility provides information directly to the nearby field trials. In this study hydrothermal coefficient (HTC) of each month was calculated during the growing season “(Fig. 1.)”. The calculations were performed “(2)” by applying formula [20]:

\[
HTC = \frac{\Sigma x}{\Sigma t \times 10},
\]

where Σ x and Σ t – sum of precipitations and temperatures in the period, when the temperature has not been lower than 10°C.

Ranges of values of this index were classified according to Sielyaninov in the modification of [21] as: HTC ≤ 0.4 extremely dry; 0.4 < HTC ≤ 0.7 very dry; 0.7 < HTC ≤ 1.0 dry; 1.0 < HTC ≤ 1.3 relatively dry; 1.3 < HTC ≤ 1.6 optimal; 1.6 < HTC ≤ 2.0 relatively humid; 2.0 < HTC ≤ 2.5 humid; 2.5 < HTC ≤ 3.0 very humid; HTC > 3.0 extremely humid.

The hydrothermal conditions during the growing stages of flax differed “(Fig. 1.)”. The relatively humid
was recorded in 2014 and 2016 (1.8 and 1.9, respectively), relatively dry in 2015 (1.2) and dry in 2018 (0.9). The very humid was recorded in 2017, especially extremely higher humidity in August, where was about 317% higher than the long-term average.

C. Statistical Analysis

MS-Excel software was used for data statistical analysis and correlations. Significant differences among the measured characteristics of flax genotypes were compared by Fisher’s protected least significant difference (LSD) tests (p ≤ 0.05). Phenotypic and genotypic coefficients of correlation for yield and agronomic traits were identified [22; 23].

III. RESULTS AND DISCUSSION

All the agronomic traits measures determined for flax were significantly (p ≤ 0.05) dependent on genotype (“Table 2”). The significant (p ≤ 0.05) highest total plant height was observed of genotypes ‘Vilani’, ‘K9-1’, ‘K9-2’ and ‘L26-1’ with the range from 82.42 to 85.35 cm, the technical plant height of genotypes ‘T36-3’, ‘T36-1’, ‘K9-2’, ‘T36-2’, ‘Vilani’, ‘K9-1’ and ‘26-1’ with the range from 64.26 to 70.58 cm and the fibre content of genotypes ‘T36-3’, ‘T36-2’, ‘S37-2’ and ‘T36-1’ with the range from 32.58 to 34.88% compared with the standard ‘Vega 2’ (ST). A study by [4], [24] has revealed that the plant technical height, fibre percentage and plant type (height, branch number, etc.) are the essential indexes for fibre flax breeding. In this study results was observed variable genetic resources where not all genotypes with highly technical height or stem yield had a great amount of fibre contents. Results have identified the diversity of flax genetic resources with perspective to find out genotypes useful for different purposes.

The significant (p ≤ 0.05) highest stem yield was observed of genotypes ‘S37-1’, ‘T36-1’, ‘K9-1’, ‘Vilani’, ‘L26-2’ with the range from 643.12 to 693.32 g m⁻² and the seed yield of genotypes ‘S37-1’, ‘Vilani’, ‘S29-2’, ‘I7-1’ with the range from 136.08 to 147.86 g m⁻² compared with the standard ‘Vega 2’ (ST). The harvest index (HI) ranged from 15.49% to 20.87% between genotypes was identified insignificant different. According to [17] the flax descriptors list all genotypes were identified medium vegetation period where average day’s number from seedling to flowering ranged from 57 to 61 days and to early yellow ripening stage from 98 to 104 days.

In this study, the genotypic and phenotypic correlation coefficient was similar in directions, while in magnitude, genotypic correlations were mostly higher than corresponding phenotypic correlations (“Table 3”).

### TABLE 2
AGRONOMIC TRAITS OF FLAX GENOTYPES

<table>
<thead>
<tr>
<th>Genotype</th>
<th>ToH, cm</th>
<th>TH, cm</th>
<th>StY, g m⁻²</th>
<th>FC, %</th>
<th>SY, g m⁻²</th>
<th>OC, %</th>
<th>HI, %</th>
<th>DF</th>
<th>VP</th>
</tr>
</thead>
<tbody>
<tr>
<td>S29-1</td>
<td>74.80</td>
<td>59.82</td>
<td>538.12</td>
<td>29.58</td>
<td>123.76</td>
<td>42.65</td>
<td>19.19</td>
<td>60</td>
<td>99</td>
</tr>
<tr>
<td>S29-2</td>
<td>74.60</td>
<td>60.30</td>
<td>630.46</td>
<td>29.28</td>
<td>145.20</td>
<td>43.13</td>
<td>19.13</td>
<td>61</td>
<td>101</td>
</tr>
<tr>
<td>S37-1</td>
<td>75.72</td>
<td>60.92</td>
<td>555.32</td>
<td>34.02</td>
<td>136.08</td>
<td>43.00</td>
<td>20.58</td>
<td>60</td>
<td>102</td>
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<tr>
<td>S37-2</td>
<td>76.86</td>
<td>62.74</td>
<td>643.12</td>
<td>29.72</td>
<td>133.88</td>
<td>43.22</td>
<td>17.64</td>
<td>60</td>
<td>102</td>
</tr>
<tr>
<td>T36-1</td>
<td>79.46</td>
<td>65.90</td>
<td>643.20</td>
<td>34.88</td>
<td>107.04</td>
<td>44.70</td>
<td>15.49</td>
<td>58</td>
<td>99</td>
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<tr>
<td>T36-2</td>
<td>80.78</td>
<td>67.88</td>
<td>600.52</td>
<td>33.68</td>
<td>114.96</td>
<td>43.85</td>
<td>17.27</td>
<td>58</td>
<td>98</td>
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<tr>
<td>T36-3</td>
<td>77.62</td>
<td>64.26</td>
<td>552.96</td>
<td>32.58</td>
<td>135.50</td>
<td>44.85</td>
<td>20.57</td>
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<tr>
<td>K9-1</td>
<td>83.36</td>
<td>69.00</td>
<td>649.06</td>
<td>28.00</td>
<td>121.68</td>
<td>43.50</td>
<td>17.15</td>
<td>61</td>
<td>103</td>
</tr>
<tr>
<td>K9-2</td>
<td>83.28</td>
<td>67.88</td>
<td>610.72</td>
<td>26.04</td>
<td>127.22</td>
<td>43.33</td>
<td>18.92</td>
<td>61</td>
<td>103</td>
</tr>
<tr>
<td>L26-1</td>
<td>85.12</td>
<td>70.58</td>
<td>693.32</td>
<td>29.26</td>
<td>125.48</td>
<td>43.23</td>
<td>16.58</td>
<td>63</td>
<td>104</td>
</tr>
<tr>
<td>I7-1</td>
<td>78.04</td>
<td>63.06</td>
<td>598.32</td>
<td>26.60</td>
<td>147.86</td>
<td>41.50</td>
<td>20.87</td>
<td>58</td>
<td>100</td>
</tr>
<tr>
<td>I7-2</td>
<td>80.54</td>
<td>65.86</td>
<td>617.12</td>
<td>27.48</td>
<td>133.36</td>
<td>42.73</td>
<td>18.40</td>
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<tr>
<td>Vilani</td>
<td>82.42</td>
<td>67.96</td>
<td>668.80</td>
<td>29.02</td>
<td>141.06</td>
<td>42.43</td>
<td>18.68</td>
<td>58</td>
<td>98</td>
</tr>
<tr>
<td>Vega 2</td>
<td>72.98</td>
<td>58.32</td>
<td>556.80</td>
<td>26.38</td>
<td>115.28</td>
<td>42.68</td>
<td>18.18</td>
<td>59</td>
<td>101</td>
</tr>
<tr>
<td>LSD 0.05</td>
<td>8.67</td>
<td>5.86</td>
<td>86.19</td>
<td>3.98</td>
<td>22.06</td>
<td>0.92</td>
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</tr>
</tbody>
</table>

ToH- total plant height, TH - technical height, StY - stem yield, FC - fibre content, SY - seed yield, OC - oil content, HI - harvest index, DF - days to flowering, VP - days to early yellow ripening stage; LSD values significant at p ≤ 0.05 are marked in bold comparing with ‘Vega 2’ (ST).
The similar results [7], [10], [25] were obtained that genotypic correlation coefficients were higher than their respective phenotypic correlation coefficients for most of the characters. A study by [26], [27] has revealed that genotypic correlations are higher because of environment had a small role in the expression of the traits, which suggests an inherent association between these traits at the genetic level. In the present study, stem yield showed a positive significant genotypic and phenotypic relationships with total plant height ($r_{y}=-0.70^{**}; r_{ph}=0.62^{*}$), technical height ($r_{y}=0.70^{**}; r_{ph}=0.57^{*}$) and phenotypic relationship with days to early yellow ripening stage ($r_{y}=0.59^{*}$). This fact suggests that flax accessions consist genotypes were showed the productivity of stem yield when are the highest plant heights and length of vegetation period. However, in this study stem yield and days to early yellow ripening stage have only phenotypic correlation where open the possibility find out for breeding of early highly productive genotypes. [28], [29] also drew similar conclusions under low correlation between these characters. The negative significant at genotypic and phenotypic level showed relationships harvest index with stem yield ($r_{y}=-0.63^{*}; r_{ph}=0.80^{*}$), total plant height ($r_{y}=-0.55^{*}; r_{ph}=-0.54^{*}$), technical height ($r_{y}=-0.59^{*}; r_{ph}=-0.54^{*}$).

The positive significant genotypic and phenotypic relationship showed between seed yield and harvest index ($r_{y}=0.76^{**}; r_{ph}=0.56^{*}$) and at phenotypic level with vessels per plant ($r_{y}=0.75^{**}; r_{ph}=0.56^{*}$) as well significant negative at genotypic level with oil content ($r_{y}=-0.53^{*}$). Similar results a findings about seed yield at flowering, VP - days to early yellow ripening stage; * − correlation significant at $p \leq 0.05$; ** − at $p \leq 0.01$

The flax yield formation of the majority of characters depends not on one factor, but on factors system and interaction between abiotic and biotic stresses. The new flax varieties should be resistant to lodging and diseases [35]. In this study the powdery mildew, anthracnose and pasmo severity index variable between the genotypes from 2015 to 2018. The powdery mildew severity index was identified the lowest range of genotypes ‘Vilani’, ‘T36-2’, ‘T36-1’ and highest ‘S29-2’ during four years period (“Fig. 2.”). The flax genotypes were identified as more susceptible to powdery mildew in the dries years. The all genotypes were showed quite low susceptible to powdery mildew with DSI range from 2.50 to 7.92% and statistically not significant between genotypes.
from 1.04 to 11.25% and statistically not significant between genotypes.

The information on the correlation of yield with related traits is the prerequisite to forming an effective plant breeding strategy aimed at its improvement. Genotypic and phenotypic correlations between yield and yield components were identified that total plant height, technical height and days to early yellow ripening stage played a major role on stem yield as well vessels per plant and harvest index on seed yield for fibre flax genotypes under Latvian condition.

Between all flax genotype were obtained most promising genotype ‘Vilani’ with complex highest resistance to fungal diseases and good lodging resistance.

V. ACKNOWLEDGEMENTS

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REFERENCE


