Breeding better Flax (*Linum usitatissimum* L.) for agronomic and consumption values under different field treatments

[1]Mohammad Mehdi Rahimi, [2]Mohammad Amin Zarei and [3]Ali Arminian

[1]Department of Agriculture, Yasooj Branch, Islamic Azad University, Yasooj, Iran;
[2]Department of Agriculture, Bushehr Branch, Islamic Azad University, Bushehr, Iran;
[3]Department of Agronomy and Plant Breeding, Ilam University, Ilam, Iran. Corresponding author: m.rahimi1351@yahoo.com

Abstract. We studies some best levels of N fertilizer (0 to 150 $kgha^{-1}$) and cultivation dates on grain yield its related characters and 5 food consumption compositions on 8 Linseed varieties at Yasooj Azad University, Iran, during 2009 and 2010 in field experiments as RBD split-plot designs. As a result, early sowings (14th March) along with moderate-to-high N fertilizer (100-150 $kgha^{-1}$) led to highest yields. Significant positive associations found between agronomic and biochemical; oil percentage and Linoleic fatty acids. Path coefficients analysis revealed interestingly that Capsule number and primary branch per plant, plant height and 1000-seed weight had the most positive direct effects on seed yield. According to PCA, first two traits, along with height and 1000-seed weight, oleic and Linoleic acids and dry weight had the most contributions, interpreting almost all the variation. Thus, to simultaneous breeding of high oil and yielding flax varieties, capsule number per plant, primary branch per plant, plant height and 1000-seed weight should firstly be considered followed by oleic and Linoleic fatty acids.

Key words*:* Flax (Linseed), grain yield, food values, multivariate analysis,

Introduction

Flax (*Linum usitatissimum* L.; n=15), or linseed, is an important oilseed crop which is the only species in the Linaceae family with economic and agronomic values (Tadesse et al., 2009). It has nutrients and pharmaceutical uses and used for edible and lightening purposes and also in animal fat and poultry diets (Khan et al., 2010). Flax seeds contain 30-45% oil, making it an important industrial crop. Due to rapid drying off, flax oil is quite valuable in dye industry. It has high unsaturated fatty acids, especially Linolenic acid (Khan et al., 2010). The yield of flax is related to e.g. number of plant per unit area, number of capsules per plant and weight of seeds per capsule. Obtaining varieties with high yield and quality for linseed depend upon applying fertilizers like N. For most crop plants, seed yield is determined (multiplied) by the product of seed number and intact seeds which are influenced by N application denoting the importance of N fertilizer.

Seed yield depends majorly on plant height, seed number per capsule, capsule number per plant, 1000-seed weight and primary branch number, respectively (Nie et al., 1995). Due to less impression of direct selection for yield, more efforts should be over indirect selection for yield components. Proper understanding of association of different traits, provide more reliable selection criterion to achieve a high seed yield (Akbar et al., 2001). Simple correlation coefficients and ANOVA tables (even in multiple-year trials) may not evolve satisfactory results in uncovering the real interrelationships among agro-biochemical characters. Nevertheless, selection for yield via highly correlated characters becomes easy if the contribution of different characters to yield is quantified using path coefficient analysis (Dewey & Lu, 1959) or PCA method a branch of multivariate approaches.

The present study was conducted to study the associations among yield, yield related and some biochemical characters (protein, oil and fatty acids compositions) in linseed under different nitrogen and planting dates to determine the best cultivars for enhance seed yield and food consumption components of flax.

Materials and methods

Eight flax (linseed) varieties viz: Atlante, Bionda, Raulinus, Astamm2.764, Somaco, Linda, Olay-ozon, and Saidabad grown in the Department of Agronomy, Yasooj Azad University, Iran (N 30°50′ , E 51°41′ , 1831 a.s.l), spring 2008-09 and 2009-10. Experimental design was a split-plot with 4 replication as RB design combined over 2 years. Following to agronomic managements, amount of seeds oil measured using Soxhlet apparatus (Soxhlet, 1879; Dorina et al., 2008), and fatty oleic, linoleic and Linolenic acids extracted using gas chromatography (GC). In addition to oil and fatty acids, seed yield ($kgha^{-1}$), harvest index

(HI), 1000-seed weight (g), plant height (PH), primary branches number per plant, capsules number per plant, and dry weight (biomass, g) were recorded following to harvest. Then mean of 10 samples were used for statistical analyses. The data were analyzed by ANOVA to determine significant differences between the 8 genotypes using SAS (Ver. 9.1, SAS Institute Inc., Cary, NC) and Minitab (version 15, LEAD Technologies, Inc, USA). ANOVA for all the traits performed as combined analysis, and path coefficients were estimated according to Dewey and Lu (1959), where seed yield (kgha-1) was kept as final dependent variable and other contributing characters (Tadesse et al., 2009) as causal variables. Furthermore, PCA analysis performed using Minitab software to determine the best relationships among characters.

Results and Discussion

ANOVA results indicated significant differences ($P<0.01$) for almost all traits among years, genotypes, N levels, sowing dates (data not shown). Thus, seed yield and its related traits and even quality traits of [oil] flax were affected by factors mentioned. Comparatively, two first sowing dates produced more (50.76 and 49.73) capsules number per plant. Moreover applying 150 and 100 $kgha^{-1}$ N, produced more capsules per plant. El-Nagdy et al. (2010) concluded that raising the levels of N fertilizer from 25 to 100% in flax enhanced seed yield and some attributed characters such as number of capsules per plant, 100-seed weight, seed yield and oil. They also referred to interaction effects of N fertilizer with bio-fertilizers and phosphorus impacts on yield and yield contributing characters.

Positive significant correlations between seed yield with most traits raised (data not shown) which confirmed previously works (Akbar et al., 2001; Mirza et al., 1996; Tadesse et al., 2009). Thus, such characters could be properly applied to improving yield through selection. Therefore, such characters could be utilized for indirect selection of yield in breeding programs. One can select simultaneously seed yield as well as high oil content by selecting for seed weight (Tadesse et al., 2009). However, some flax genotypes have been developed which contained low levels of Linolenic acid, making them suitable as edible-oil (Green, 1986; Rowland, 1991). Simultaneous selection is of target, i.e. genotypes with high oil contents may have higher grain yield, higher seed weights, and higher oleic acid content, as selection criteria for obtaining entries with high yield with higher oil, oleic acid and weight. This suggests possibility of simultaneously improvement of seed yield as well as oil content, as Tadesse et al. (2009) implied. The importance of such characters on seed yield and simultaneous selection of them are discussed later through PCA (Fig. 1).

Principal component analysis (PCA) of seed yield and other traits

The PCA was (Fig. 1) resulted in 4 most informative PCs with eigenvalues of 8.45, 1.71, 1.14 and 0.31, respectively, together accounted for almost all the entire variability (97%). According to PC1, seed yield, plant height, capsule number, oil and Linolenic acid contents had relatively higher contributions to the total morphological variability, proved by path coefficients analysis etc (data not shown). Primary branch number, 1000-seed weight, linoleic content, dry-weight and protein content exerted the most variability in this trend. According to the first two PC biplot (Fig. 1) including loadings, 8 genotypes were categorized within 3 groups. One group comprising of Linda, Olay-ozon and Saidabad had the higher protein contents, the second, including Somaco and Astamm2.764 varieties contained higher primary branch per plant. The 3rd group had higher values for the remained characters. PCA showed a clear differentiation between flax cultivars from each others. Most of the variation (70%) is explained by the first two PCs in a biplot, accountef for 85% of the variation, which can interpret the near-real differentiation of the cultivars and morpho/biochemical characters studied. This is an illustrative and fascinating result which is likely unique in linseed experiments.

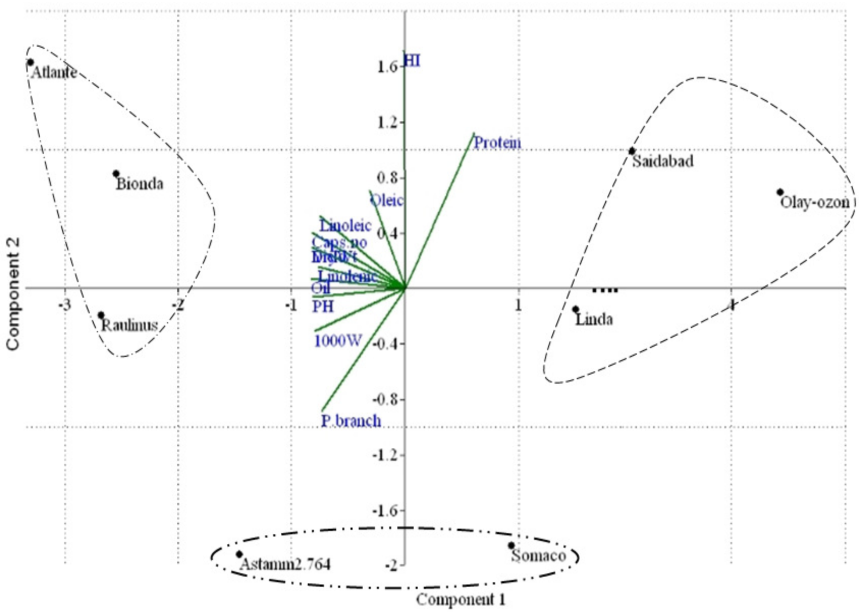

Figure 1. Biplot of principal component analysis. P.branch: primary branch per plant; 1000w: 1000-seed weight; PH: plant height; Caps.no: capsule number per plant; HI: harvest index.

All the linseed varieties differentiated in 3 groups, i.e. Saidabad, Olay-ozon and Linda varieties located in group 1, Atlante, Bionda, and Raulinus in group 2 and finally Somaco and Astamm2.764 in 3rd group. Vromans (2006) examined 110 flax accessions and a wild species from different locations (Dutch, French and Canada etc) to investigate the hereditary basis of important traits such as fiber quality and achieved a biplot of two first PCs together explained approximately 22% of the variation. As he pointed out, the PCA indicated a clear differentiation and also high inter-population distance supported the differentiation between the two morphological groups. According to the biplot, e.g. cultivars Saidabad and Olay-ozon had more protein contents and so on. Thus this biplot could be used as a vital instrument to categorize, differentiate and address the genetic entities in breeding decisions.

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