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FODDER PRODUCTION

Indicator Traits for Classifying Forage Soybean Varieties According to Purposeful Use (Hay, Silage, Green Fodder)

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Abstract—A study of 76 morphological, agronomic, and biological characteristics of 270 forage soybean accessions from the Vavilov Research Institute of Plant Industry (VIR) collection revealed seven traits (type of plant apex, degree of shoot twining, number of plant leaves and nodes, leaf weight and size, width of seed hilum) allowing classification of a variety according to purposeful use: hay, silage, or green fodder. It is noted that the number of plant leaves is an indicator trait for indirect assessment of green mass yield of the accessions.

Keywords: soybean, variability, indicator traits, factor and discriminant analysis

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INTRODUCTION

Soybean varieties are classified according to two main types of use: grain and forage, which at present is not taken into consideration in the Russian Federation Register of Breeding Achievements. Meanwhile, fodder production practice attests to the need to distinguish not only an independent category of forage varieties but also from it a group of a more narrow purposeful use, namely: hay, silage, and green fodder. The technologies of preparing and designating each of these types of feed are different and require the appropriate material. A sine qua non for all forage varieties is a high content of protein, mineral substances, and vitamins. But at the same time, green fodder varieties a priori should be relatively tall, with a non-coarse green mass, capacity for its intensive growing after cutting, and with slowly aging leaves. Plants used for hay and grass meal should be characterized by a high yield of dry matter and protein, thin branches, intensive branchiness and leafiness, weak pubescence, small well-retained plant leaves, and small pods and seeds. Silage varieties should also provide a high yield of green mass and dry matter and at the same time have an increased sugar content.

For a long time breeders have understood the need for specialization of forage varieties [1]; however, methods of breeding them don't exist at present. A study of the diversity of forage soybean accessions from the VIR collection made it possible to distinctly differentiate them, which is valuable for choosing parent material in breeding varieties having purposeful use [2, 3].

Polymorphism of forage soybean varieties is determined by variability of qualitative (type of growth, habit of plants, etc.) and quantitative (stem thickness, number of plant branches, leaves, and nodes, leaf weight and size, etc.) traits. For choosing varieties with the required characteristics from this diversity, it is necessary to study the regularities of variability and interrelation of their agronomic and biological traits under various environmental conditions and to reveal traits determining the accumulation of vegetative mass. This issue, including with respect to forage soybean, has been elucidated little in the literature [1, 2, 4].

The purpose of the present work was to investigate variability of the set of biological and agronomic traits of forage soybean accessions from the VIR collection to determine ecologically stable indicator traits related to green mass yield and allowing the identification of differentiation of gene pools as the parent material for breeding varieties having purposeful hay, silage, and green fodder use.

MATERIALS AND METHODS

The field experiments were conducted for 3 years at VIR's Kuban Experiment Station (Krasnodar krai). We evaluated 270 forage soybean accessions from the VIR collection with respect to 76 morphometric, agronomic, phenological, and biochemical traits as well as resistance to a number of pathogens in accordance with the Comecon International Classification of the Genus *Glycine* Willd. [5].

Factor structure of morphometric, biological, and economically valuable forage soybean traits (1989, 1992, and 1994)

Factor	FD% (percentage of variance)	Leading traits
F_1	12.6	Type of growth, 1000 seed weight, width of pods and seeds
F_2	9.9	Interphase periods
F_3	5.2	Plant height, length of the middle internode
F_4	6.4	Seed quality (protein and oil content), degree of twining of stem, seed color
F_5	5.7	Weight of plant, leaves, and branches, number of leaves, nodes, and branches, stem diameter, 1992
F_6	5.5	Leaflet length and width, leaf shape, leaf elongation, petiole width, 1992, 1994
F_7	3.6	Length of apical leaf and inflorescence
F_8	5.8	Weight of plants, branches, and leaves, leaf and petiole length and width, 1989
F_9	3.8	Weight of plant, branches, and leaves, number of leaves, 1994
F_{10}	3.0	Pubescence color, susceptibility to diseases, content of antinutrients in grain and protein in green mass

The years of the investigation (1989, 1992, and 1994) were characterized by contrasting meteorological conditions. In 1989 and 1992, the sum of active temperatures was respectively 2888.0 and 2370.0°C and the precipitation amount during the growth period was 394.7 and 334.3 mm, which was considerably higher than the normal. In 1994, the sum of active temperatures was 3578°C and precipitation 177.1 mm.

Statistical processing of the data included a factor analysis of a system of correlations according to the principal component method as well as an analysis of variance of eigenvalues of principal components (factor loads) in the ANOVA/MANOVA module [6–8]. Discriminant and canonical analyses (Statistica 7 software package) was used for revealing traits allowing classification of the parent material according to purpose of fodder use.

RESULTS AND DISCUSSION

When conducting factor analysis of the variability of interrelations of 76 traits of the studied accessions, the parameters of the same trait were analyzed separately during each year. The data united during the 3-year investigation showed that the revealed variability was related to ten principal components (correlation pleiades) reflecting the structure and level of intervarietal interrelations under various weather conditions (table).

Traits related to green mass yield, which were strongly influenced by the environment, formed three different pleiades. Yield traits of just one year were grouped in each pleiade; their structure was the same independent of the year and included the traits weight of plant, branches, and leaves and number of leaves. Traits during the 3-year investigation were united in pleiades of seed weight and size, growth period, plant height, and biochemical composition of seeds. High correlations between traits within these factors remained independently of the growing conditions.

Factor analysis of the data performed for each year separately revealed pleiades whose compositions changed insignificantly over the years. The structure of most pleiades was similar to that obtained as a result of a total analysis during the 3 years, but environmental conditions clearly affected the level of correlations. In 1989, which was more favorable for soybean development, the maximum role in variability of the set of traits played the factors related to plant leaf size and height, and in dry 1994 the factors were distinguished by a minimum value of the correlation between these traits. The change in the strength of the relations was determined to a considerable degree by the change in the range of their variation: it was maximum in 1989 and minimum in 1994. Within the limits of the pleiades we observed insignificant variations of the relations, which didn't change their general direction.

Thus, we revealed a persistent ecologically stable relation between plant weight and its number of leaves. Therefore, the plant leaf number trait can be used as an indicator trait in an indirect evaluation of green mass yield of accessions.

It should be noted that correlations important for soybean breeding were found in the factor pleiades of the structure of interrelations of all agronomic and biological traits studied. In particular, negative genotypic dependences were found between protein content in the green mass and growth period length, dry matter content, plant weight, number of flowers in raceme, and raceme length. On the whole, accessions developing a large vegetative mass were characterized by a relatively low protein content in it and prolonged growth period. Early-ripening accessions were distinguished by a relatively high protein content in the green mass and its low yield.

A positive correlation was observed between green mass protein content and apical leaf size, presence of a bud at the hilum, number of seeds in the pod, and

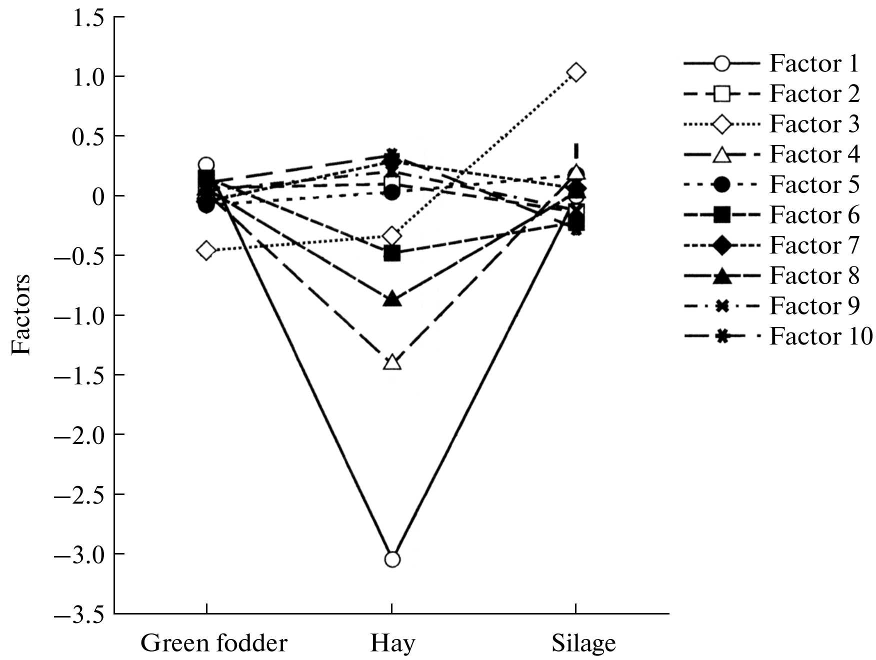

Fig. 1. Average values of factor loads for groups of use of accessions (1989, 1992, and 1994 data); traits of ten factors, see table.

small seed size. The relation between protein content in the green mass and grain was insignificant. A very strong negative correlation was noted between seed oil and protein content. A positive correlation was established between oil content in grain, plant weight, and growth period duration. In some accessions we found an interrelation between protein content in the vegetative mass and infection by diseases, as well as a positive correlation between content of antinutrients (proteinase inhibitors) and resistance of the accessions to Soja virus.

To reveal traits most important for the breeding soybean for various forage use, we investigated the reliability of the differences between means of the factor loads with respect to groups of use. For the analysis we used the data of all years and each year separately (Fig. 1).

Accessions of the hay group differed reliably from those of the other two groups in the values of the loads of factors F_1 (seed and growth type trait factor) and F_4 (biochemical seed composition factor). Thus, varieties being grown for hay are distinguished by growth habit, small leaves, increased number of seeds in pod, small-seed size, dark seed color, and high protein content in the seeds. Accessions of the silage group differed reliably from others with respect to F_3 (plant height factor) and were characterized by a greater plant height in comparison with the green forage and hay accessions (Fig. 1). The results of analyzing the factor values obtained for the 3 years and for each year separately were analogous.

To single out the traits most significant when classifying the accessions into groups according to forage types, we performed stepwise discriminant analysis with successive elimination of the traits. Reliable differences of the groups were obtained for growth habit, type of apex, plant height, hilum width, and presence of a bud (remnant of funicle) at the hilum. The leaf elongation index, leaf width and length, pod width, and seed length and width were also important, but were unstable with respect to character of manifestation in different years of the investigation. In wetter 1989, when the conditions for soybean development were ideal, the differences of the groups in leaf elongation and traits related to its size were substantial, and in dry 1994 seed traits had importance. The canonical analysis revealed regularities of the intergroup variation of traits in the space of two discriminant functions (R1 and R2), Fig. 2a–c). In this case, the hay varieties stood out most strongly among the accessions of the other purposes of use in number of plant leaves and their weight, leaflet size, and hilum width. The silage and green fodder varieties formed indistinctly delineated groups overlapping one another to a considerable extent. Varieties of the green forage type were not similar to silage varieties in type of apex, number of plant nodes and leaves, degree of twining, and plant height. Consequently, the most important traits for separating varieties according to purpose of use are the following: number of plant leaves, number of nodes, type of apex, hilum width, and leaf weight and size.

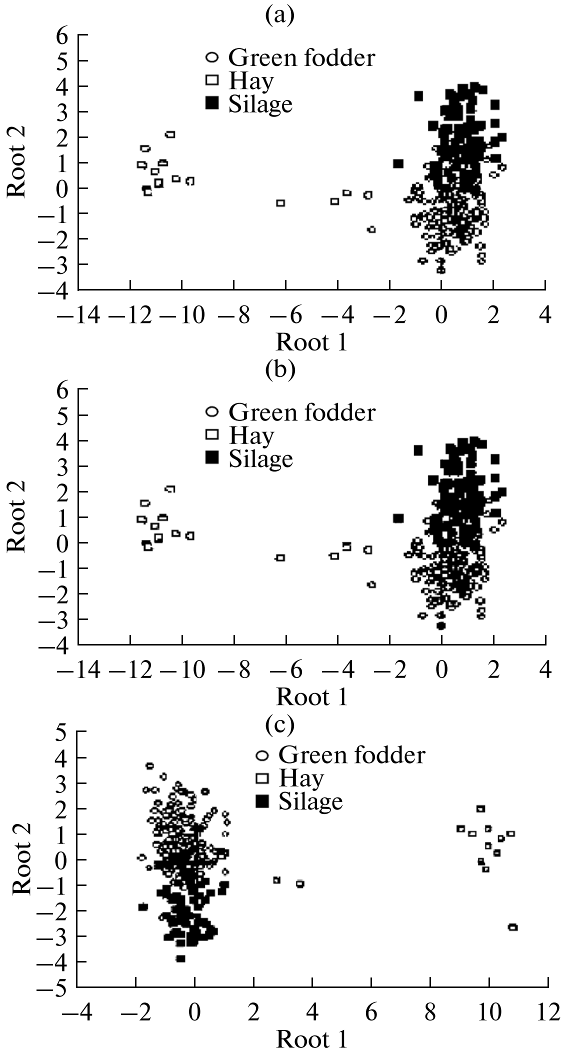

Fig. 2. Location of accessions in space of canonical axes: (as) 1989; (b) 1992; (c) 1994.

Thus, in breeding soybean varieties for different types of forage, in the initial stages we recommend selecting for hay varieties accessions with a large number of plant leaves (average number ≥77.6 in the flowering stage and ≥200.0 in the pod forming stage) and small leaf size (average length 3.5–6.1 cm and average width 4.0–8.0 cm); for green forage varieties, accessions with a determinate growth type, large number of plant nodes (39.7–124 in the pod forming stage), and large leaves (average length 11.9–15.0 cm and average width 7.8–11.5 cm); for silage varieties, with a plant height ≥85.2 cm in the pod forming stage, large number of nodes on the main stem (≥16.8 in the pod forming stage) and leaf size as for the green fodder accessions (average length 11.7–16 cm and average width 7.6–10.8 cm).

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