Periods of development and dynamic parameters of white lupin (Lupinus albus L.) yield formation

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Abstract. There is a problem of vegetable protein deficiency for feed, processing and nutrition in many countries: to produce or import? White lupin cultivation in Russia is important due its high potential seed and protein yield. The breeding program for creating cultivars of white lupin with a determinant type of growth and the study of the dynamic parameters of the yield formation was carried out in many years of research in the northern part of the Central-Chernozem region of Russia. Experiments were conducted at the experimental field in Tambov region. Cultivar is one of the main components of resource-saving technologies. For the first time in Russia, under these conditions, cultivars of white lupin with a determinant type of growth were created. Among them are Start, Gamma, Delta, Dega, Deter1, Timiryazevskiy with different plant architectonics.

1 Introduction

Seeds of leguminous crop Lupinus albus L. contain 32-44% protein and 10-13% fat. The nitrogen-fixing ability of plants ensures stable crop yields without fertilizers [1]. Recently, there has been a steady demand for Lupinus albus L. grain for use as a high-protein component for the production of feed for all types of animals and poultry. The high content of protein, dietary fiber, low fat content, currently allow to evaluate lupin as an alternative to animal protein, a possible raw material for obtaining lupin flour, including for the preparation of bread products. Biologically active compounds of lupin grains are useful in the prevention and treatment of certain human diseases. Lupinus albus L could represent a suitable alternative protein source capable of replacing soy without loss of quantity and quality of livestock products [4]. In addition to the nutritional value in animal feeding, lupin successfully adapts to low-fertile soils, is not demanding on nutrition elements, and is a good precursor for many crop rotation cultures, including in the production of organic products.[9]. The advantages of fish diets supplemented with lupin have been established, where there is a growing demand for vegetable protein to replace protein fish meal [10]. From a nutritional point of view, white lupine seeds have a high protein content - from 32.9% to more than 36.0%.

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By origin, white lupin belongs to late-maturing species that did not mature earlier in the conditions of the northern part of the Central Chernozem region of Russia. The introduction of white lupine into this region became possible thanks to the breeding work of the scientists of the RSAU-MAA. As a result of long-term experiments, the first experimental samples of plants with a determinant growth activity type were obtained. They served as the basis for the creation at the experimental site in the conditions of the Tambov region to create a new unique source material for the start of breeding of new Lupinus albus L. varieties, maturing in the conditions of the Central Chernozem region. Thus, new varieties of Lupinus albus L. appeared: Start, Manovitsky, Gamma, Delta, Dega, Deter 1. A new stage in scientific research was the development of theoretical foundations for the justification of the timing of yields formation based on the biology of crops for the leguminous family.

The purpose of the research is to establish the variability of plant development production stages based on the dynamic parameters of Lupinus albus L., to determine the contribution of individual stages of organogenesis during the growing season, yield properties, trends in the dependence of the yield level on climatic factors in the conditions of climate change for the Central Chernozem region of the Russian Federation.

2 Materials and Methods

In the experiment scheme, different types of cultivars were identified, which differ significantly in the morphoarchitectonics of plants: branching, shoot formation, growth dynamics, stages of organogenesis and their duration. In conditions of sufficient moisture supply of the growth period, the most complete manifestation of varietal characteristics is noted, especially in terms of stem branching and shoot formation (Table 1).

Table 1. Types of varieties depending on the architectonics of plants.

Varieties	Plant architectonics
Deter 1 (type I)	There are no side shoots, beans are formed on the main shoot
Start, Gamma (type II)	Shoots of the first order are shortened, formation of beans on shortened shoots
Dega, Delta (type III)	Side shoots of the first and second order are long
Manovitsky (type IV)	Shoots of the first-third and higher orders are formed only with sufficient moisture supply.

The studies were carried out in conditions of slightly acidic leached, medium-sized chernozems. For sowing, an early date was used, the seeding rate was 0.5 million pieces of germinating seeds per hectare. The experimental plots were maintained in a weed-free state [3].

The methodology included the determination of dynamic parameters of plant photosynthesis in the field agricultural system: Leaf Area Index (LAI); Leaf area duration (LAD) 10^3 m^2 d ha^{-1}, Net Assimilation Rate (NAR), g m^{-2} d^{-1}, Total Wet and Dry Matter Accumulation (TWM, TDM), t ha^{-1}, Crop Growth Rate (CGR), kg ha^{-1} d^{-1}, Number of pods and seeds m^{-2}.

3 Discussion

The experiments were based on the establishment and fixation of photosynthetic parameters of plants correlating with the formation of the main elements of Lupinus albus L. productivity, directly related to the variability of lupin's agrocenosis, yield properties, and dynamic characteristics of plants, including changes in protein productivity. The structure of the dynamic system for the productivity of Lupinus albus L. It is typical for most plants of the Fabaceae family. The most significant periods of growth processes for lupine have been established, successively replacing each other: sowing-seedlings (the beginning of growth), and the period characteristic of the end of vegetation - maturation, changes in plant parameters in terms of the absence of plant green parts and leaves. More detailed stages of crop development have been established in the dynamic system of lupin photosynthesis (Table 2).

Table 2. Photosynthetic system (stages of maturation).

Shoots - flowering (beginning) (stage I)	Beginning of shoots - opening of the first flower on the plant
Flowering - fruit formation (stage II)	first flower opening on a plant – end of flowering
Fruit (bean) growth (Stage III)	End of fruit formation – phase of shiny beans.
Seed filling (stage IV)	Outflow of assimilates into seeds; increase to maximum values of dry weight of seeds
Maturation (stage *V*)	Loss of moisture in fruits.

The variability of the duration of the maturation growing season and individual periods in years with different meteorological conditions is an important indicator for farmers and enterprises producing lupin grain to assess the opportunities and risks in growing this crop. The plant development period from the germination period up to the maturation period in the Central Chernozem region is subject to variability, and is determined to a greater extent by the adaptive capabilities of the variety and climate conditions, on average varies from 70 to 120 days [4] (Table 3).

Table 3. Duration of vegetation, days.

No.	Year	Variety					Average	Sigma*	V%
		Start	Gamma	Delta	Dega	Deter 1			
1	2007	94	94	94	94	90	93	1.60	1.7
2	2008	114	114	115	114	105	112	3.72	3.3
3	2009	103	102	105	102	97	102	2.64	2.6
4	2010	77	77	78	77	73	76	1.74	2.3
5	2011	90	98	98	98	93	95	3.32	3.5
6	2012	102	102	103	102	96	101	2.53	2.5
7	2013	102	102	104	103	96	101	2.80	2.8
8	2014	102	102	102	102	96	101	2.40	2.4
9	2015	112	111	114	114	100	110	5.23	4.7
Average		100	100	101	101	94	99	2.66	2.7
Sigma		10.7	10.0	10.4	10.4	8.4			
V%		10.7	10.0	10.3	10.4	8.9			

*Sigma in the tables is the standard deviation, V% is the variation coefficient.

It was the smallest in dry years (2007, 2010). When comparing varieties, the shortest growing season was for the variety forming fruits on the main stem - Deter 1.

A change in the architectonics of plants in drought conditions was noted - the development of varieties occurred with a significant reduction in the growing season by 28-39 days. In some years of research (namely 2009, 2011-2012), the vegetation conditions were characterized by excessive aridity, the temperature regime reached a maximum with a minimum of precipitation, especially during critical periods of plant development (2-3

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stages). The studied varieties with architectonic features, such as the formation of first-order shortened shoots, the formation of beans on shortened shoots (varieties Start, Gamma), and varieties with long side shoots of the first and second order (varieties Dega, Delta) were characterized by simultaneous maturation, differed by a shorter growing season, in general, over the years of research shorter by 10-13 days. Varietal variability of the duration of the "shoots – maturation" period, estimated by the variation coefficient, was noted 3 times less than under the effect of climatic changes during the years of the experiment. The conditions of 2007 and 2010 were dry, the acceleration of maturation was noted by an average of 25-34 days, compared with 2008 and 2015.

The weather conditions of the availability of the photosynthetic system of plants during the periods of vegetation had a great influence on yield formation and its variability (Table 4).

Table 4. Seed yield (t ha^{-1}) and its variability.

No.	Year	Variety					Average	Sigma	V%
		Start	Gamma	Delta	Dega	Deter 1			
1	2007	2.4	2.38	2.67	2.34	2.26	2.41	0.14	5.7
2	2008	3.85	3.98	3.84	3.9	3.28	3.77	0.25	6.6
3	2009	3.45	3.43	4.16	3.78	3.19	3.60	0.34	9.3
4	2010	2.0	2.0	2.16	1.56	2.0	1.94	0.20	10.4
5	2011	3.58	3.16	3.07	3.53	3.58	3.38	0.22	6.6
6	2012	4.06	3.78	3.53	3.78	4.06	3.84	0.20	5.2
7	2013	2.0	2.31	2.11	2.17	2.07	2.13	0.10	4.9
8	2014	3.24	3.09	3.92	3.35	2.12	3.14	0.58	18.6
9	2015	3.82	5.54	6.1	5.89	4	5.07	0.97	19.0
Average		3.16	3.30	3.51	3.37	2.95	3.26	0.19	5.8
Sigma		0.76	1.02	1.16	1.19	0.80	0.93		
V%		24.2	30.8	33.1	35.4	27.1	28.5		

4 Conclusion

Based on studies conducted in different countries with leguminous crops, it was found that white lupin is the most promising plant as an alternative to soy. Experiments were conducted at the experimental field in Tambov region. Cultivar is one of the main components of resource-saving technologies. For the first time in Russia, under these conditions, cultivars of white lupin with a determinant type of growth were created. Among them are Start, Gamma, Delta, Dega, Deter1, Timiryazevskiy with different plant architectonics. Care adapted to the conditions of the region, ripen steadily, grain yield 3-5 t / ha. The length of the periods and the dynamic parameters of the yield formation of white lupin for each period are determined. Among the parameters are the leaf area index (LAI), the total dry matter accumulation (TDM), the crop growth rate (CGR), leaf area duration (LAD), net assimilation rate (NAR), and yield components. Period II is critical in yield formation. Variability of parameters is determined in connection with weather conditions and seed yield. Our research has proven the pattern of dynamic dependence for determinant varieties of white lupine varieties in the formation of productivity and protein accumulation. crop formation and assess the degree of influence of weather conditions on dynamic indicators and seed productivity.

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