Productivity of white lupine (*Lupinus albus* L.) in different sowing periods in the conditions of the Southern Trans-Urals

A A Khalimullina, A V Sozinov, I N Porsev and I A Subbotin

Kurgan State Agricultural Academy named after T S Maltsev, Kurgan, 641300, Russia

E-mail: savrey@ya.ru

Abstract. The article describes the results of a three-year field experiment studying the effects of sowing periods on the crop structure, biometric indicators and productivity of white lupine varieties Degas and Gamma. The experiment was conducted in 2015-2017 on the leached chernozem of the experimental field of Kurgan State Agricultural Academy in the forest-steppe zone of Kurgan Region. The first sowing period corresponded to the physical soil maturity (the third decade of April - the first decade of May), the subsequent sowing periods were 6-8 days after the first one. Only in 2015, the full ripeness phase was not achieved (the third sowing period). The optimal sowing period was the first one: the yield of lupine grain varied from 2.5 to 14.9 t/ha.

1. Introduction

The crop industry has to meet the needs of animal husbandry, since the national food security is closely linked with an increase in livestock production. This sector depends on the production of feed and its quality. The food must contain protein and amino acids.

The protein content in the seeds of leguminous crops (soybeans, peas, beans, lentils, lupins, fodder beans, rank, chickpeas) ranges from 22 to 45%, depending on varieties. This is several times more than in the seeds of cereals (corn, barley) which form a basis of the diet of animals. Among leguminous plants, two plants have the highest protein content and its amino acid composition - soybeans and lupine (white, narrow-leaved and yellow). Their seeds contain more protein than the seeds of other leguminous crops [1-4].

Only soybean and white lupine can satisfy the needs of animal husbandry [5, 6]. According to research data, white lupine is the most productive in the soil and climatic conditions of Russia. Unlike soybeans, it has higher grain yields and green mass. In addition, it has a relatively high protein content in the grain and green mass. Today, organic farming is becoming popular. White lupine may become one of the main crop rotations. It has broad prospects for being used in the agricultural industry as it belongs to the category of valuable crops [7].

The costs of white lupine growing are lower than profits derived from its sales. In addition, white lupine is more technological than soybeans, peas and other legumes. Its beans attach strongly to the stalk, do not crack when ripening, the seeds do not crumble. Therefore, losses are minimal.

Researchers and agricultural producers have accumulated extensive experience in lupine cultivation. When developing and optimizing adaptive-landscape lupine cultivation technologies, it is necessary to use the research results [8-13].

For the conditions of the forest steppe of the Southern Trans-Urals, white lupine is not a typical plant. Many scientists beleive that the temperature regime of this area is insufficient for lupine grain ripening
However, proper selection of growing technologies, early ripening varieties may be suitable for producing green mass and grain. Scientifically based cultivation technologies used for white lupine will allow agricultural enterprises to introduce this crop into the crop rotation. One of the main advantages of white lupine is its resistance to drought and low temperatures. It enriches the arable layer with nitrogen, removes nutrients that are difficult to reach. White lupine can be cultivated without the use of nitrogen fertilizers which allows to obtain high-protein environmentally friendly products [15].

The purpose of the study is to identify the optimal sowing term for white lupine varieties Degas and Gamma which will allow for production of high quality grain in the conditions of the forest-steppe of the Southern Trans-Urals.

2. Materials and methods
The studies on the impact of sowing terms on productivity of white lupine varieties in the conditions of Kurgan region were carried out in 2015-2017 on the basis of the experimental field of Kurgan State Agricultural Academy. To assess the biological potential of white lupine, black fallow was chosen as a precursor. The soil was leached chernozem, slightly humusified, thin, light loamy, characterized by the following indicators: humus content - 3.04%; cation exchange capacity - 24.7 mmol/100 g, the degree of saturation - 78%, pH of the salt extract - 5.1 units; density - 1.17 g/cm³, density of the solid phase - 2.63 g/cm³, total porosity - 55.2%, wilting humidity - 7.04%; mobile phosphorus - 75 mg/kg, exchangeable potassium - 131 mg/kg; thickness of horizons A + AB - 32 cm.

Weather conditions were favorable for white lupine. 2015 was characterized by a deficient regime of effective temperatures and excessive precipitation during seed formation and ripening. At the initial stage, the air temperature exceeded the average long-term values by 2.8°C, the amount of precipitation was 40% of the norm. The June HTI was 0.33 units. During July-August, the air temperature was below the mean annual values by 1.8–2.9°C and precipitation exceeded the norm by 110 and 20%, respectively. The HTI of these months was 2.03 and 1.70 units. In September, the weather was favorable for harvesting: the air temperature was close to the average long-term indicators (+ 0.2°C from the norm) and the amount of precipitation was 10 mm (23% of the norm). In May 2016, the average monthly air temperature was higher than the multiyear average by 0.4°C, and in 2017, it was lower by 0.1°C. The amount of precipitation was 43% and 164% of the mean annual data. In summer months, the conditions were favorable. In June, the air temperature was higher by 0.2°C and 0.9°C, the amount of precipitation was 66 mm and 55 mm which was slightly different from the average annual. In July 2016, the temperature was at the level of the average annual values, and the amount of precipitation was 132 mm or 220% of the norm. In July 2017, the temperature was higher than the average value by 0.2°C, and the amount of precipitation was 50 mm or 83% of the norm. In August, the temperature increased by 4.9°C and 0.8°C, and the amount of precipitation fell to 2 mm (4.3% of the norm), while in 2017, it was 60 mm.

In 2015, white lupine seeds of varieties Degas and Gamma were used for experiments. These varieties are most suitable for soil and climatic conditions of our area. Varieties Degas and Gamma are universal. For Degas, the grain yield is 4.1, for Gamma - 4.5 t/ha. Degas is a taller variety (80-90 cm) than Gamma (60-80 cm). It has larger seeds with a mass of 270-350 g in comparison with Gamma’s seeds with a mass of of 250-300 g. Both types are early ripening: duration of the growing season is 110-120 days in Gamma, and 115-130 days in Degas. Varieties are characterized by field resistance to fusarium, cracking of beans and seed shedding. The content of protein is 35-38%, fat - 8-10%, alkaloids - 0.03-0.05% [16].

To determine an optimal variety and sowing term, lupine was sown in three terms: when the soil reached physical ripeness and 6-8 days after depending on weather conditions (Table 1).

The accounting area of plots was 10 m². The seeding depth was 3-4 cm. The seeding rate was 1 million viable seeds per hectare. Structural analysis of the harvest was carried out for 1 m². Placing options in repetition were randomized. The repetition was four-fold.
Table 1. Sowing terms for varieties of white lupine depending on weather conditions, the experimental field of Kurgan State Agricultural Academy

| Sowing date | 2015          | 2016          | 2017          |
|-------------|---------------|---------------|---------------|
| 1st         | April 30      | May 4         | May 11        |
| 2nd — control | May 6         | May 11        | May 33        |
| 3rd         | May 14        | May 18        | June 1        |

Plant stand density, plant mass, plant height, number of beans per plant, weight of beans per plant, number of seeds per legume, number of seeds per plant, weight of seeds per plant, mass of 1000 seeds, mass of seeds per 1 m² were determined. The biological grain yield was converted to t/ha [17].

Statistical processing of the results was performed by the method of dispersive analysis of the data of one-factor experiment according to B.A. Dospekhov [18].

Table 2. The structure and productivity of lupine variety Degas, the experimental field of Kurgan State Agricultural Academy, 2015-2017

| Term of sowing | Height of plants, cm | Plant density, pieces/m² | Weight of one plant, g | Mass of beans in one plant, g | Number of seeds in 1 bean, pcs. | Seed mass in one plant, g | Weight of 1000 seeds, g | Seed mass per 1 m², g |
|---------------|----------------------|--------------------------|------------------------|-------------------------------|-------------------------------|--------------------------|-------------------------|----------------------|
| term 1 (04/30)| 49.7                 | 90.2                     | 6.60                   | 2.75                          | 4.35                          | 3.08                     | 8.48                    | 2.78                 |
| term 2 (06/05)| 50.6                 | 93.0                     | 5.83                   | 2.88                          | 3.78                          | 2.91                     | 8.38                    | 2.38                 |
| term 3 (14/05)| 50.1                 | 90.0                     | 5.52                   | 2.54                          | 2.67                          | 3.03                     | 7.69                    | 1.66                 |

Average for 3 years

| Term 1 (05/11) | 62.0 | 73.4 | 20.6 | 8.98 | 14.2 | 3.56 | 33.4 | 9.89 | 304  | 665  |
| term 2 (22/05) | 63.3 | 67.1 | 17.2 | 7.49 | 11.5 | 3.61 | 28.2 | 8.09 | 286  | 445  |
| term 3 (01/06) | 59.9 | 84.7 | 14.9 | 6.75 | 9.52 | 3.62 | 25.3 | 6.75 | 256  | 557  |
3. Results and Discussion

The seedlings appeared on the 12th day; the flowering began on the 40th day. At the beginning of the growing season, there were weed plants (Convolvulus arvensis), white martian (Chenopodium album), and the schirenés (Amaranthus retroflexus). However, the number of weeds did not exceed the economic threshold of damage; herbicide treatment was not performed.

In 2015, the seedlings were eaten by sandy sandworms (Opatrum sabulosum L.). To prevent it, the seedlings were treated with Fascord insecticide at the rate of 0.1 l/ha with a working fluid consumption of 200 l/ha.

The analysis of structural and biometric indicators of lupine plants is presented in Table 2. Plants of the third sowing term (2015) did not reach full ripeness until permanent snow covering. Therefore, productive indicators of this variant were the lowest ones. In 2016-2017, all three terms have reached full ripeness.

The results of the experiment showed that the plants sown in the first decade of May had the greatest height (for the second sowing term in 2015 and 2016, and for the first sowing in 2017). The greatest mass of a single plant was in the first variant. The same is true for the number of beans per plant, the mass of beans, the number of seeds and the mass of seeds per plant. The largest mass of seeds per m² was observed in the first variant.

On average, over three years of research, given that in 2015, plants of the third sowing period did not reach full ripeness and there were losses of the crop, productivity per unit area ranked second after the control variant.

The structure of Gamma variety is presented in Table 3. The growing season of 2015 did not allow the lupine plants of the third sowing period to reach full ripeness.

Table 3. The structure and productivity of lupine variety Gamma, the experimental field of Kurgan State Agricultural Academy, 2015-2017

| Term of sowing | Height of plants, cm | Plant density, pieces / m² | Weight of one plant, g | Number of beans per 1 plant, pieces | Mass of beans per 1 plant, g | Number of seeds per 1 bean, pcs. | Number of seeds per 1 plant, pieces | Seed mass per 1 plant, g | Weight of 1000 seeds, g | Seed mass per 1 m², g |
|---------------|----------------------|----------------------------|------------------------|------------------------------------|-----------------------------|--------------------------------|-----------------------------------|------------------------|------------------------|-------------------------|
| 2015          |                      |                            |                        |                                    |                             |                                |                                    |                        |                        |                         |
| term 1 (04/30)| 43.5                 | 93.2                       | 8.23                   | 2.93                               | 5.65                        | 3.31                           | 9.68                               | 3.55                   | 367                    | 331                     |
| term 2 (06/05)| 45.3                 | 90.0                       | 7.20                   | 2.75                               | 4.95                        | 3.18                           | 8.73                               | 3.00                   | 344                    | 270                     |
| term 3 (14/05)| 42.1                 | 88.4                       | 6.95                   | 2.80                               | 4.10                        | 2.86                           | 8.00                               | 2.24                   | 280                    | 198                     |
| NDS          |                      |                            |                        |                                    |                             |                                |                                    |                        |                        |                         |
| 2016          |                      |                            |                        |                                    |                             |                                |                                    |                        |                        |                         |
| term 1 (04/05)| 49.2                 | 55.0                       | 19.9                   | 12.5                               | 14.6                        | 3.71                           | 45.9                               | 10.0                   | 218                    | 552                     |
| term 2 (05/11)| 55.9                 | 31.7                       | 17.7                   | 12.0                               | 12.8                        | 3.20                           | 37.9                               | 8.9                    | 234                    | 278                     |
| term 3 (18/05)| 47.3                 | 39.0                       | 16.9                   | 11.0                               | 12.3                        | 3.41                           | 37.7                               | 8.5                    | 225                    | 331                     |
| NDS          |                      |                            |                        |                                    |                             |                                |                                    |                        |                        |                         |
| 2017          |                      |                            |                        |                                    |                             |                                |                                    |                        |                        |                         |
| term 1 (05/11)| 59.4                 | 80.0                       | 38.2                   | 17.7                               | 27.8                        | 3.92                           | 69.3                               | 18.6                   | 268                    | 1487                    |
| term 2 (22/05)| 62.1                 | 32.7                       | 28.4                   | 12.7                               | 20.0                        | 3.91                           | 49.2                               | 13.6                   | 276                    | 444                     |
The weight of one plant was higher in the first variant, in 2015, it was 8.23 g, in 2016, it was 19.9 g, in 2017, it was 38.2 g. The number of beans, the mass of beans, the number of seeds and the mass of seeds per one plant were higher in the first variant during all research years. Productivity of seeds per unit area was also higher.

On average, the plants of the first and third sowing periods were more productive than plants of the second one. However, in 2015 the plants of the third period did not reach full ripeness. Therefore, the first sowing period remains the most advantageous.

The analysis of productivity of Degas variety showed that 2017 was more favorable for its growth and development (Table 4). The biological grain yield varied from 4.1 to 10.4 t/ha, while in 2016, the yield limits were 6.0–7.1 t/ha, and in 2015, there were 1.5–2.5 t/ha. In 2015, there were the least favorable weather conditions. However, the yield was 2.2–2.5 t/ha in the first and second variants.

For Gamma variety, in 2017, the conditions were more favorable in comparison with 2015 and 2016. In 2017, the biological yield changed from 4.5 to 14.9 t/ha; in 2016 - from 2.8 to 5.5 t/ha; in 2015 - from 2.0 to 3.3 t/ha.

### Table 4. Biological yield of white lupine grain, t/ha, experimental field of KSAA, 2015-2017

| Term of sowing | Degas | Gamma |
|----------------|-------|-------|
|                | Yield | Deviation | Yield | Deviation |
| term 1 (04/30) | 2.50  | 0.29 | 3.31 | 0.61 |
| term 2 (06/05) | 2.01  | -   | 2.70 | -   |
| term 3 (14/05) | 1.49  | -0.72 | 1.98 | -0.72 |
|                | 0.25  | 0.05 |
| term 1 (04/05) | 7.08  | 0.07 | 5.52 | 2.74 |
| term 2 (05/11) | 7.01  | -   | 2.78 | -   |
| term 3 (18/05) | 5.97  | -1.04 | 3.31 | 0.53 |
|                | 0.78  | 0.78 |
| term 1 (05/11) | 10.37 | 6.23 | 14.88 | 10.44 |
| term 2 (22/05) | 4.14  | -   | 4.44 | -   |
| term 3 (01/06) | 9.25  | 5.11 | 7.17 | 2.73 |
|                | 0.34  | 0.28 |
| Average for 3 years | 6.65  | 2.20 | 7.90 | 4.59 |
|               | 4.45  | -   | 3.31 | -   |
|               | 5.57  | 1.12 | 4.15 | 0.84 |
On average, Gamma variety was more productive than Degas variety in the first sowing period and less productive in the second and third ones.

4. Conclusion
It can be concluded that when cultivating white lupine for grain on leached chernozem of the forest steppe of the Southern Trans-Urals, the first sowing period was the most optimal (the end of April - the first decade of May when the soil reaches physical ripeness). It was the most optimal for both Degas and Gamma varieties. In addition, during the research years, white lupine reached the stage of full maturation in all the variants, except for the third one in 2015. Thus, the authors have proved that in the conditions of the Southern Urals, it is possible to cultivate white lupine for grain. When sown early, the yield can be 6.6-7.9 t/h.

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