Development of adaptive technology for cultivation and processing of rosebay willow-herb (Chamaenérionangustifolium)

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Abstract. The propagation methods of rosebay willow-herb were studied on the basis of theoretical and experimental studies, the optimal size of the feeding area of one plant in a field was described and established. The efficiency of cultivating these plants depending on the time of sowing in winter greenhouses and the field planting scheme was determined, scientific and practical justification of the feasibility of cultivating rosebay willow-herb as a raw material for the processing industry in the North-Eastern part of Tambov Region was given in order to obtain dry vegetable concentrate for the production of soft drinks, syrups, natural additives for functional enrichment of food products. A non-waste concentrate production technology was developed and implemented using gentle modes and intensive processes, such as two-stage vacuum-pulse drying, vacuum extraction.

1. Introduction
Medicinal herbs are the most promising sources in food and medical industry. Now they are successfully applied in medicine worldwide. In the state pharmacopoeia of Russia, the list of medicinal herbs is limited, which significantly reduces the possibility of creating effective phytoperparations produced by the industry. In this regard, the task of finding and introducing new medicinal herbs into industrial processing in order to create therapeutic and preventative drugs and functional food products based on them seems quite relevant relevant [1-5]. Such a plant is rosebay willow-herb (Chamaenérionangustifolium) or more commonly known as rosebay. Its medicinal properties are determined by therapeutic use and functionality.

The purpose of the study was to develop the elements of the technology for growing and producing products from rosebay willow-herb, which provide the possibility of its cultivation and processing in the production conditions of Tambov Region.

2. Materials and methods
Modern plant growing technologies are based on an objective assessment of the initial physiological state of plants, and this provides the opportunity to control growth and development factors. “One of the most notable physiological phenomena is plant growth. A prophet appears from the germinating seed. A young plant is formrf from the seedling under normal nutritional and lighting conditions after..."
a few days. This plant extends the stem, increases the number and size of leaves, it grows” [3, 6, 7]. During the plant growth, a sequential phase change occurs. Their duration depends on external and internal factors. The study of cultivation and processing, in particular the processes of drying and extraction of a rosebay willow-herb was based on the works of such authors as Danilin S.I.,Perfilova O.V., Rodionov Yu.V., Rudobashta S.P., Lykov A.V., Filonenko, Zorin A.V., Kuzmenko S.L. [8-11].

3. Effects of adaptive technology
The life cycle of rosebay willow-herb plants is divided into the following periods of growth and development: seed, vegetative and reproductive.

The duration of rosebay willow-herb vegetation consists of two periods – greenhouse (seedling) and field. The sowing of rosebay willow-herb seeds was carried out in winter greenhouses for three terms. The sowing was carried out in cassettes (Fig. 1a) on April 26, the seedlings of rosebay willow-herb are planted in the field (Fig. 2b) when the danger of freezing is over and the soil temperature is set to a depth of 15 cm not lower than 10°C. Rosebay willow-herb was planted with a width between rows – 70 cm and distances in a row – 15-20 cm.

![Figure 1. Rosebay willow-herb plants grown in cassettes (a) and at different times in a greenhouse (b)](image)

The growing season is significantly different from the sowing period and varies from 120 days with sowing on 20.03 to 150 days with sowing on 25.01. We noted that the age of seedlings does not significantly affect the development phases after field setting, on 05.07 the plants approached the first harvesting at the first sowing period and by 09.07 at the last sowing period.

Thus, we established an optimal sowing date of 20.03. In winter greenhouses all plants were more amicable to all phases of development and by the time of harvesting caught up with plants of earlier sowing dates.

The most manageable factor affecting plant development is the planting pattern or food area. Using various planting schemes, we regulated the distribution of soil under one plant, light regime, nutrient supply and moisture.

The optimal area of food and placement is one of the most important issues in the technology of any agricultural crop, since the quality of the crop, mechanization opportunities and labor costs depend on the correct solution.

By changing this area, we get a comprehensive effect on plant growth. At the same time, not only the volume of soil at the disposal of each plant and, therefore, the level of its provision with moisture and nutrients changes, but also the light regime of plants.

In our opinion, the thickening of planting deteriorates the nutritional conditions of plants. Besides, not only the mass of leaves, but also the number of laid leaves also decreases.

If with an increase in the density of plants, we see a decrease in the number of leaves, then their height increases as they thicken.

Thus, when studying the increasing density the standing of plants at 111,000 pcs/ha was 57 cm in the flowering phase for the broad-leaved willow-herb, and 102 cm – for the narrow-leaved willow-herb, respectively.
Apparently this is caused by the fact that thick planting deteriorates the lighting conditions of leaves and plants, as a result of the struggle for this factor, the stems and leaves stretch gaining a higher height compared to plants grown in widely spaced plantings.

The survival of plants for harvesting depends on many environmental factors. In this regard, observations were made to study the yield of plants of various sowing periods taking into account their field survivability. The data of our observations are presented in Table 1. Plants grown in the greenhouse from different plantings were planted on the same day (26.04) according to the 70*15 scheme.

Table 1. Yield of rosebay herbage depending on the sowing time (average for three years)

| Type            | Greenhouse sowing time | Yield formula | Weight of plant, g | Willow-herb yield taking into account of plants, g/ha |
|-----------------|------------------------|---------------|--------------------|-----------------------------------------------------|
| narrow-leaved   | 25.12                  | 52.4          | 322.8              | 16.1                                                |
|                 | 18.02                  | 85.6          | 312.6              | 25.0                                                |
|                 | 20.03                  | 97.2          | 284.2              | 26.2                                                |
| broad-leaved    | 25.12                  | 50.3          | 131.6              | 6.6                                                 |
|                 | 18.02                  | 83.6          | 128.7              | 10.2                                                |
|                 | 20.03                  | 96.8          | 120.9              | 11.2                                                |
| LSD05           |                        |               |                    | 10.2                                                |

The study of the willow-herb sowing periods revealed that a later sowing period is most suitable for growing willow-herb in the conditions of Tambov Region. So, when sowing on 20.03, the plants that took root were almost twice as large as the earlier sowing period – 25.12 in both studied species. At the same time, the weight of one plant at an earlier sowing period was slightly higher and reached 322.8 g against 284.2 when sown on 20.03, respectively. Besides, these indicators affected the yield of willow-herb per unit area. The highest yield was achieved when sown on 20.03 and reached 26.2 for narrow-leaved willow-herb and 11.2 in broad-leaved willow-herb, respectively. At earlier sowing periods, the yield decreased to 16.1 for narrow-leaved willow-herb and to 6.6 t/ha for broad-leaved willow-herb. This is caused by low survivability of plants after planting in the field.

The grown rosebay willow-herb is to be processed into a concentrate with subsequent creation of functional beverages. The studies made it possible to determine the ratios of raw components and extraction, enrichment and drying modes, on the basis of which a sketched technological scheme for the production of concentrates was developed (Fig. 2).

The withering stage is carried out in order to remove excess moisture and to make the stems and leaves of the narrow-leaved willow-herb as a result of the turger loss. A number of biochemical changes occur when the plant is withered: the number of phenolic compounds decreases, chlorophyll is partially destroyed, there are changes in the complex of carbohydrates, proteins, amino acids and essential oils, the activity of enzymes changes, the area of parts of the plant, its mass and volume decreases. The content of ascorbic acid is reduced. The formation of a specific aroma begins. When squeezed in a hand, the ground parts of the plant shall be able to form a crumb. Moisture content of rosebay willow-herb decreases from 75-78% to 55-60%.

Grinding of rosebay willow-herb is carried out in order to obtain a given fine fraction and destroy the cell structure. As a result of damage to cellular structures, in particular the protoplasm, the content of vacuoles is mixed with cytoplasm, and the resulting cell juice flows to the surface of twisted leaves, enveloping them. The latter contributes to the intensive oxidation of phenolic compounds by air oxygen and the activation of oxidative enzymes. The higher the proportion of broken cells of rosebay willow-herb, the fuller the biologically active substance of plants are used, the extractability of the infusion increases and the quality of the drink is higher.
| Process                          | Temperature | Humidity | Notes                                                                 |
|---------------------------------|-------------|----------|----------------------------------------------------------------------|
| Drying                          | T=40-55°C, W=5-7% |          |                                                                       |
| Crushing of raw material        |             |          |                                                                       |
| Withering                       | T=22-30°C, t=6-12h |          |                                                                       |
| Fermentation                    | T=20-30°C, t=6-12h |          |                                                                       |
| Enrichment of narrow-leaved fireweed | T=30°C, t=4h |          |                                                                       |
| Vacuum concentration            |             |          |                                                                       |
| Packing (liquid concentrate) (QA) |             |          |                                                                       |

Figure 2. Development of technology for production of concentrate for soft drinks based on rosebay willow-herb

Fermentation refers to biochemical processes and proceeds with the help of its oxidative enzymes, mainly polyphenol oxidase. During the fermentation process, rosebay willow-herb completely loses the green color and smell of greens, acquiring a dark brown color and a pleasant aroma of the fermented product. By the end of fermentation, the bitter taste of non-oxidized tannin and other phenolic compounds disappears and a pleasant, softer taste resembles that of black tea is formed.

To select a drying method for concentrate based on rosebay willow-herb, a series of experiments was conducted to study the kinetics of drying samples under conditions of convective, convective vacuum – pulse and combined convective vacuum – pulse drying (Table 2). The concentrate prepared on the basis of rosebay willow-herb was charged into a convective dryer tray. Convective drying was carried out as follows: the raw material was put on a tray grid through which the drying agent (air) passed using a blower, the air flow rate was 3 m/s. At regular intervals, the raw material was weighed to an accuracy of ±0.5 g.

Convective vacuum-pulse drying was carried out as follows: the raw material placed on the trays in the drying chamber was blown with hot air at temperatures below the denaturation temperature of the biologically active substances in the raw material (blowdown stage – heating); then the hot drying agent was stopped and vacuum was created in the drying chamber (vacuum drying stage).
Convective drying was carried out for 35 minutes, then for 25 minutes a convective vacuum was carried out – pulse drying. The final time of the first drying period was determined by critical moisture content, and the final time of all drying with the necessary moisture content was 8±0.5%.

**Table 2.** Experimental results of rosebay willow-herb concentrate drying

| Convective drying | Convective vacuum – pulse drying | Two-stage convective vacuum – pulse drying |
|-------------------|---------------------------------|------------------------------------------|
| Drying time, min  | Moisture content, %             | Drying time, min                        | Moisture content, %             | Drying time, min                        | Moisture content, %             |
| 0                 | 95.0                            | 0                                       | 95.0                            | 0                                       | 95.0                            |
| 10                | 86.3                            | 10                                      | 84.2                            | 10                                      | 80.0                            |
| 20                | 81.2                            | 20                                      | 79.0                            | 20                                      | 62.0                            |
| 30                | 76.4                            | 30                                      | 74.2                            | 30                                      | 44.0                            |
| 40                | 71.3                            | 40                                      | 69.2                            | 35                                      | 35.0                            |
| 50                | 66.5                            | 50                                      | 64.4                            | 39                                      | 24.0                            |
| 60                | 61.7                            | 60                                      | 59.4                            | 43                                      | 17.0                            |
| 70                | 56.4                            | 70                                      | 54.6                            | 47                                      | 13.0                            |
| 80                | 52.6                            | 80                                      | 50.2                            | 51                                      | 9.5                             |
| 90                | 46.5                            | 90                                      | 44.6                            | 55                                      | 8.5                             |
| 100               | 36.3                            | 100                                     | 35.7                            | 59                                      | 8.0                             |
| 120               | 26.7                            | 120                                     | 26.4                            | -                                       | -                               |
| 140               | 20.2                            | 140                                     | 15.6                            | -                                       | -                               |
| 160               | 18.1                            | 160                                     | 8.5                             | -                                       | -                               |
| 180               | 10.3                            | -                                       | -                               | -                                       | -                               |
| 200               | 8.3                             | -                                       | -                               | -                                       | -                               |

In accordance with the obtained experimental data it is recommended to use a two-stage convective vacuum: 1 stage: drying agent temperature – 105±5°C, coolant speed – 3 m/s, drying time – 35±2 min; 2 stage: drying agent temperature – 55±5°C, drying time – 24 min. The end of the first period was determined by the temperature increase inside the vegetal raw material (temperature curve inside the material is not shown).

Extraction is aimed at releasing extractive substances from solid vegetable raw materials with the help of aqueous, aqueous-alcoholic extraction agents. The discharge pressure also significantly intensifies the process, and low temperatures allow creating a gentle mode of the process, preserving the biologically active substances as much as possible.

Filtration is aimed at purification of an extract from coarse extraction cake and fine solid particles of extracted raw material.

Rosebay willow-herb is enriched by soaking dried powder with extract and keeping at temperature of 30°C for 4 hours. In the process of soaking biologically active substances extract together with the extraction agent, they are transferred to powder particles having a capillary-porous structure and cause its swelling. The soaking stage envisages enrichment of the narrow-leaved willow-herb with an aqueous-alcoholic extract of biologically active substances. As a result of prolonged soaking, there is almost complete penetration of substances from the extract into the powder of rosebay willow-herb, its saturation with vitamins, organic acids and phenolic compounds.

When enriching fermented willow-herb with narrow-leaved extracts, in order to determine the necessary ratio of powder to extract volume, it is necessary to take into account the coefficient of water absorption. The experiments confirmed that soaking for 4 hours ensured a sufficiently complete penetration of substances from the extract into the dried raw material.
Further, enriched concentrates are dried, during drying, along with removal of excess moisture, the finished product is made stable during storage, and the corresponding organoleptic characteristics of the finished product are formed.

Packing is the process of packing finished product weighing from 100 g to 1000 g in sealed foil bags for sealing.

The storage of enriched concentrate should be carried out in clean, dry, well-ventilated rooms with a relative air humidity of 60-65% (but not higher than 70%), preventing proximity to perishable and sharply smelling products.

The economic efficiency of growing and primary processing of willow-herb depends on many factors, including the yield of herbage, its quality and loss during drying. The assessment of economic indicators was based on the yield of herbage was determined taking into account the loss of cultivation, the cost of seeds for laying the plantation, drying, the sale price of these products, and data on the production costs of growing and processing willow-herbs. The main parameters for the calculation of economic indicators are presented in Table 3.

**Table 3. Economic efficiency of willow-herb cultivation and primary processing**

| Economic indicators                  | Narrow-leaved willow-herb | Broad-leaved willow-herb |
|-------------------------------------|---------------------------|--------------------------|
|                                     | 2018          | 2019          | 2020          | 2018          | 2019          | 2020          |
| Herbage yield                       | t/ha          | 25.2          | 26.2          | 26.8          | 11.2          | 13.2          | 13.2          |
| Weight after drying                 | t/ha          | 5.0           | 5.4           | 5.6           | 2.2           | 2.6           | 2.8           |
| Cost of seeds                       | rub/ha        | 1500          | -             | -             | 1500          | -             | -             |
| Cost of seedlings                   | rub/ha        | 370000        | -             | -             | 370000        | -             | -             |
| Material and monetary costs         | rub/ha        | 16300         | 15200         | 15500         | 16300         | 15200         | 15500         |
| Drying costs                        | rub/ha        | 63500         | 68580         | 68680         | 33500         | 38580         | 38680         |
| Willow-herb cost                    | rub/ha        | 451300        | 83780         | 84180         | 421300        | 53780         | 54180         |
| Dried willow-herb cost              | rub/t         | 120000        | 130000        | 130000        | 120000        | 130000        | 130000        |
| Sales revenue                       | rub/ha        | 600000        | 702000        | 728000        | 264000        | 338000        | 364000        |
| Profit                              | rub/ha        | 148700        | 618220        | 643820        | -157300       | 284220        | 309820        |
| Production profitability, %         | %             | 32.9          | 731.9         | 764.8         | -37.3         | 528.4         | 571.8         |

The economic efficiency of willow-herb growing was determined per 1 ha. It was established that when growing willow-herb, the main costs fall on laying the plantation in the first year, since we used potted seedlings grown in a greenhouse complex. This year, the cost price of willow-herb reached 451300 rubles, and the profitability level of narrow-leaved willow-herb was 32.9% and 37.3% for broad-leaved willow-herb. However, the second year of use of plantations allowed increasing profitability several times. Thus, the profitability in growing and primary processing of narrow-leaved willow-herb reached 737.9%, and that of broad-leaved willow-herb reached 528.4%. Data on primary processing of willow-herb in 2020 showed an increase in profitability by 33% against the background of yield increase.

**4. Conclusion**

The obtained results make it possible to recommend growing willow-herb in the conditions of Tambov Region using winter greenhouses when sowing seeds on 20.03. Since the costs of growing pay off in the second year and the ability to reproduce willow-herb through seeds in industrial conditions make this crop popular in primary processing for the production of dry enriched concentrates.
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