The effectiveness of the introduction of promising varieties and new technology in the cultivation of common hops

A V Korotkov¹, N N Pushkarenko², A O Vasiliev², V I Medvedev³, A P Akimov³ and G S Yunusov⁴

¹Head of Scientific and Practical Center for Research in Hop Production, Chuvash State Agricultural Academy, 29 K/Marks Street, Cheboksary 428000, Russian Federation
²Technical Service Department, Chuvash State Agricultural Academy, 29 K/Marks Street, Cheboksary 428000, Russian Federation
³Department of Transport And Technological Machines and Complexes, Chuvash State Agricultural Academy, 29 K/Marks Street, Cheboksary 428000, Russian Federation
⁴Department Of Mechanization of Production and Processing of Agricultural Products, Mari State University, 1 pl. Lenin, Yoshkar-Ola 424000, Republic of Mari El, Russian Federation

E-mail: 3777222@bk.ru

Abstract. In the conditions of the middle zone of the Russian Federation, incl. the Chuvash Republic, it is possible to cultivate early, mid-early and mid-season hop varieties: Tsivil'skii, Druzhnyi; Sumer', Krylatskii, Podvyaznyi, Mikhailovskii, Favorit, Flagman, Feodal, Forvard and Fakir with a growing season of 95-120 days, with a certain ratio of bitter substances and essential oils, with the appropriate cultivation technology. On the newly restored plantations, the location of the pillar rows - 10 m, for the use of general purpose tractors, it is recommended to hold the tab of hops with 3.3 m spacing between rows, and 1.1 m in the rows between the plants. The use of autumn pruning of the main rhizomes of hops accelerates the emergence of sprouts and reduces the duration of the phases of growth and development in the spring time. The use of new technologies and innovative techniques allow reducing the cost of 123 person days in comparison with the traditional technology.

1. Introduction

National economic significance of hops is due to the fact that cones are a mandatory and indispensable raw material for brewing. They are also used in medicine, bakery and perfume industry.

Hop is a laborious culture. Labor costs for its cultivation are 120-180 people / days per 1 ha [1]. Currently, the Russian Federation is taking the next steps to revive the hop industry. The task is to provide Breweries of the country with high-quality domestic product. The solution of this issue will require a large - scale technical re-equipping of the industry through the introduction of modern and innovative technology, and the use of promising varieties of hops suitable for meteorological conditions of the middle zone of the Russian Federation. The proposed technology includes the use of a set of technological measures, the most important of which are the mechanization of labor-intensive processes, including pruning the main rhizomes, hanging supports, preparing holes for planting, laying of hop-
gardens, combining technological operations in one pass of the unit [2-4]. In order to improve the existing technology, research has been conducted on the development of highly efficient innovative methods of hop cultivation based on the implementation of intensive varieties - Podvyaznyi, Krylatskii, Fakir, Feodal, Forvard, Favorit, Flagman, which allow minimizing costs and means to increase plant productivity. Work continues on the study of hop varieties with a combination of different characteristics, the main of which are belonging to different groups of ripeness, biochemical type, resistance to wintering conditions, phytophages and phytopathogens not only in Russia, but also in other countries of the world - in the Czech Republic, Ukraine, Poland and Germany [5-8].

2. Materials and methods
The component composition of bitter substances and essential oils was investigated by HPLC (High Pressure Liquid Chromatography) and Gas liquid chromatography. Extraction of bitter substances, according to the method, was carried out using methanol (methyl alcohol). Various elements of technology of cultivation of hop ordinary with a combination of an agronomic assessment of receptions were studied. The methods of direct accounting, visual assessments and field observations of plants were applied in the studies.

When selecting varieties for use in a production environment, the main economic and biological features of hops are essential: the length of the growing season, the color of the main and lateral sprouts, the shape and size of the cones and the bush, the degree of disclosure of scales, productivity, alpha-acid content, resistance to damage by pests and diseases, suitability of the variety for mechanized harvesting. Also, the responsiveness of the hop variety to various types of mineral fertilizers, its environmental sustainability and adaptability to wintering conditions, requirements for growth and development, attitude to soils and biochemical characteristics.

The duration of the frost-free growing season in the central part of the Russian Federation, incl. Chuvash Republic, rarely exceeds 115-120 days, so in such conditions it is possible to cultivate early, medium early and mid-season hop varieties: Tsivil'skii, Druzhnyi; Sumer', Krylatskii, Podvyaznyi, Mikhailovskii, Favorit, Flagman, Feodal, Forvard and Fakir with a growing season of 95-120 days, with plantings on chernozem, gray forest, sod-podzolic soils, with a certain amount of effective temperatures and moisture. Late-ripening varieties in our region do not reach the technical ripeness phase, during wintering they suffer from high soil moisture, low temperatures, and are affected by various root rot and hop bacteria: Fusarium rot (Fusarium oxysporum Schlä.), gray rot (Botrytis cinerea Pers.), sclerot rot (Sclerotinia sclerotiorum Lib.), penicillous rot (Penicillium sp.), rhizoctonosis (Rhizoctonia sp.), a diffuse form of downy mildew and mild bacterial rot (Erwinia carotovora (Jones.) Holl) [9-11].

The composition of hops has a decisive influence on the quality of beer. Bitter resin, alpha and beta acids, cohumulone, colupulone; essential oils myrcene, caryophyllene, farnesene, humulene, alpha and beta silinen give the beer special bitterness and aromatic properties [12].

It is noted that in order to reduce the annual cycle of hop development and to facilitate the work of hop growers in the spring, autumn pruning of the main rhizomes over the first pair of kidneys is carried out in the second decade of October until the top layer of soil freezes [13]. Various authors emphasize that it is recommended to use green manure crops on hop-gardens in order to improve the agrochemical and physical properties of the soil. Also, feeding or the first hilling series with ammonium nitrate at a dose of N60 or complex fertilizers N45P25K45, and the second - to a depth of 15-20 cm with a dose of N60P45K45 or N75P45K45 with simultaneous harrowing. It is necessary to carry out lime treatment of hop-gardens once in 5 years.

As a result, the efficiency of the use of mineral fertilizers increases by 20-30 % [14].

3. Results and discussion
Agroecological features of hop varieties are different, so the Feodal variety is characterized by intensive spring regrowth, the Flagman variety has low winter hardness, lunges make up to 10-15%. The productivity and quality of hops is reduced when damaged by aphids, mites and defective powdery mildew. Attitude to damage and damage to various types of phytophages and phytopathogens is average
in the Druzhnyi, Mikhailovskii varieties. Krylatskii, Podvyaznyi, Sumer', Favorit, Flagman, Feodal varieties are more stable. A sum of effective temperatures from 1800 to 2000 °C and moisture of at least 250-300 mm is required (Table 1) for normal growth and development of hops in the conditions of the Russian Federation. All varieties are suitable for mechanized cleaning.

The biochemical composition of cones varieties of domestic selection is very diverse. The content of bitter substances, essential oils and their components depends on the variety, place of growth, mineral nutrition, weather conditions and the quality of primary post-harvest processing.

Table 1. The main characteristics of hop varieties recommended for cultivation in the conditions of the Russian Federation.

| Varieties       | Vegetation period (days) | Sum of effective temperatures, °C | Cold resistance | Resistance to major pathogens |
|-----------------|--------------------------|-----------------------------------|-----------------|-----------------------------|
| Druzhnyi        | 103-110                  | 1800-1900                         | high            | average                     |
| Tsivil'skii     | 95-105                   | 1800-1900                         | high            | high                        |
| Krylatskii      | 112-120                  | 1900-2000                         | high            | high                        |
| Mikhailovskii   | 110-120                  | 1900-2000                         | high            | high                        |
| Podvyaznyi      | 110                      | 1800-1900                         | high            | high                        |
| Sumer'          | 106-117                  | 1900-2000                         | high            | high                        |
| Favorit         | 102                      | 1800-1900                         | average         | high                        |
| Fakir           | 106                      | 1800-1900                         | high            | high                        |
| Faraon          | 104                      | 1800-1900                         | high            | high                        |
| Feodal          | 103                      | 1800-1900                         | high            | high                        |
| Flagman         | 112                      | 1800-1900                         | high            | high                        |
| Forvard         | 104                      | 1800-1900                         | average         | high                        |

Chernozem, gray forest and sod-podzolic soils have the most favorable effect on yield. Moisture - 250-300 mm. Suitability to the mechanized processing of hop-gardens is noted. Recommended planting scheme 2,5x1,2; 3,0x1,1 or 3,3x1,1 m.

Regionalized varieties contain cohumulone of 16.9-26.3 per cent, and the ratio alpha/beta of 0.69-1.51 shows the attitude of an aromatic or bitter-aromatic type (Table 2).

Table 2. Biochemical characteristics of common hop varieties.

| Components      | Podvyaznyi | Krylatskii | Sumer' | Favorit | Faraon | Feodal | Flagman | Forvard | Fakir |
|-----------------|------------|------------|--------|---------|--------|--------|---------|---------|-------|
| Alpha acids, %  | 7.9        | 5.7        | 6.6    | 3.9     | 3.8    | 4.0    | 5.5     | 2.9     | 5.2   |
| Beta acids, %   | 5.5        | 3.8        | 4.6    | 5.4     | 3.6    | 5.7    | 7.9     | 5.4     | 4.5   |
| Alpha/beta      | 1.4        | 1.5        | 1.4    | 0.7     | 1.0    | 0.8    | 0.7     | 0.5     | 1.4   |
| Cohumulone, %   | 23.2       | 26.3       | 25.8   | 19.2    | 16.9   | 20.0   | 18.2    | 17.7    | 19.8  |
| Colupulone, %   | 46.4       | 48.2       | 46.8   | 40.5    | 34.5   | 39.5   | 37.1    | 34.1    | 37.4  |
| Total ml / 100g.| 1.45       | 0.9        | 1.0    | 0.40    | 0.80   | 0.27   | 1.37    | 0.46    | 0.41  |
| Myrcene, %      | 46.0       | 34.0       | 30.0   | 28.3    | 43.7   | 25.4   | 25.1    | 42.9    | 37.3  |
| Caryophyllene, %| 9.3        | 15.8       | 13.9   | 8.3     | 6.6    | 12.3   | 10.4    | 5.7     | 9.8   |
| Farnesene, %    | 12.2       | 1.7        | 5.5    | 21.0    | 12.6   | <0.01  | 22.4    | 16.9    | 14.4  |
| Humulene %      | 17.8       | 42.8       | 43.8   | 23.0    | 16.0   | 35.4   | 26.8    | 13.7    | 17.0  |
The content of myrcene, which determines the aroma of beer wort, in varieties is 25.1-46.0%; caryophyllene - 5.7-15.8%. The greatest amount of essential oils is found in bitter and aromatic varieties Podvyaznyi, Krylatskii, Sumer' and Flagman.

According to the results of many years of research, innovative methods of cultivation of hops with minimal labor and money are proposed. Thus, it was recommended to plant new plantations into the planting furrow to a depth of 28 cm, both in free and in columnar rows by stem cuttings or annual hop saplings according to the 2.5x1.2 scheme; 3.0x1.1 m, and newly restored hop-gardens by placing long-pillar rows after 10 m, for the use of general purpose tractors, when laying, use a row spacing of 3.3 m, and plant the rows in the rows through 1.1 m. With timely and high-quality planting, the survival rate of stem cuttings and annual seedlings will be 75-80; 90-95%, and the first year of the growing season allows receiving 1-3; 3-5 c / ha, on the second - 5-8; 8-12 centners per hectare, and the costs for such planting are no more than 15 people. days / ha.

In order to reduce or completely eliminate the weed in the rows in early spring, the introduction of soil herbicides is recommended, followed by embedding with a boring unit. In order to reduce the annual cycle of hop development and to facilitate the work of hop growers in the spring, autumn pruning of the main rhizomes over the first pair of kidneys is carried out in the second decade of October until the top layer of soil freezes. As a result, due to the effective use of reserves of productive moisture and photosynthetic radiation, the phase of germination and technical ripeness of plants is accelerated in the next year. This reduces the period of growth and development of hops, which allows starting harvesting cones in the early stages.

After mechanized pruning, in order to improve the agrochemical and physical properties of the soil, regardless of the timing of pruning of the main rhizomes, to conduct continuous sowing of hop-gardens with green manure crops (mustard, rape), locally tape two-fold feeding of vegetative plants at a distance of 20-25 cm from the row or at the first hilling with ammonium nitrate in a dose of N45 or complex fertilizers N45P45K45, and in the second - to a depth of 15-20 cm with a dose of N30P45K45 or N45P45K45 with simultaneous harrowing and to carry out liming hop-gardens once every 5 years. As a result, the efficiency of the use of mineral fertilizers increases by 20-30 %.

| No. | Name of works                               | Traditional technology | New technology | Labor saving | Increased productivity |
|-----|---------------------------------------------|------------------------|---------------|-------------|------------------------|
| 1   | Introduction of herbicides                  | -                      | 2             | -2          | -                      |
| 2   | Horrowing of hop-gardens                    | 0.2                    | 0.2           | -           | -                      |
| 3   | Trimming the main rhizomes                  | 33                     | 2             | 31          | 10                     |
| 4   | Stretching the string over the row instead of pin pegs | 25                     | 2.5           | 22.5        | 10                     |
| 5   | Supports mounting                           | 27                     | 8             | 19          | 3.4                    |
| 6   | Fixing lower ends of the supports           | 25                     | 2.5           | 22.5        | 10                     |
| 7   | Planting stalks for support                 | 10                     | 10            | -           | -                      |
| 8   | Frame                                       | 10                     | 1             | 9           | 10                     |
| 9   | Removal of lower leaves, side branches, weeds | 20                     | 1             | 19          | 20                     |
| 10  | Interrow loosening, hillling with mineral fertilizers | 2                      | 2             | -           | -                      |
| 11  | Spraying with pesticides                    | 2                      | 2             | -           | -                      |
| 12  | Other mechanized transport operations       | 5                      | 3             | 2           | -                      |
| 13  | Harvesting                                  | 75                     | 75            | -           | -                      |
| 14  | Drying of hops on PCB and pressing          | 4                      | 4             | -           | -                      |
With mechanized pruning of the main rhizomes, productivity increases by 2 times, and with hanging supports, only 8 people / days are spent per 1 ha (Table 3).

The lowest leafiness and high productivity of varieties of domestic selection of hops contribute to an increase in the daily volume of gross collection of cones from 1.5 to 4.0 tons with mechanized harvesting.

4. Conclusions
In the conditions of the middle zone of the Russian Federation, incl. the Chuvash Republic, it is possible to cultivate early, mid-early and mid-season hop varieties: Tsivil'skii, Druzhnyi; Sumer', Krylatskii, Podvyaznyi, Mikhailovskii, Favorit, Flagman, Forward and Fakir with duration of the vegetation period of 95-120 days. With placement of plantings on chernozems, gray-forest and sod-podzolic soils.

As a result of biochemical evaluation of cones, it was found that Tsivil'skii, Mikhailovskii, Favorit, Faraon, Flagman, Forward and Fakir varieties belong to the aromatic type. Sumer', Krylatskii, Podvyaznyi and Fakir varieties - to the bitter-aromatic type. Druzhny Variety - to the bitter type.

It is advisable to plant the new hop-garden according to the scheme 2.5x1.2; 3.0 x1.1 m, and the newly restored plantations, the location of the columnar rows after 10 m, the tab - with row spacing of 3.3 m. The arrangement of plants in rows of 1.1 m.

The use of autumn pruning of the main rhizomes of hops accelerates the emergence of sprouts and reduces the duration of the phases of growth and development in the spring time.

The lowest leafiness and high productivity of varieties of domestic selection of hops contribute to an increase in the daily volume of gross collection of cones with mechanized harvesting.

The use of new technologies and innovative techniques allow reducing the cost of 123 person days in comparison with the traditional technology.

Typically, gray forest soils found in the extreme south-eastern part of forest - Glossic, Greyzemic, Luvic Phaeozems (Abruptic, Clayic, Albic) on Cretaceous clay eluvium, occupy an insignificant area of 2 hectares.

References
[1] Zakharov A I, Makushev A E, Zakharov D A and Dobrova A N 2017 Resource conservation in the production of hop raw materials (on the example of the Chuvash Republic) Bull. Chuvash State Agricul. Acad. 3 pp 105-10.
[2] Medvedev V I, Kazakov Y F, Pushkarenko N N, Smirnov P A and Vasilev A O 2017 The current level of mechanization of cultivation of hops in the Chuvash Republic: problems and direction of development Proceedings Intern. Acad. Agrarian Educ. 37 pp 27-31.
[3] Dmitriev Y P, Medvedev V I, Akimov A P, Dmitrieva O Y, Dmitriev S Y, Maksimov A N and Andreev V A 2018 Machine technology for the cultivation of hops Bull. Kazan GAU 2 (49) pp 86-92.
[4] Zakharov A I 2016 Factors of intensification in the hops cluster of Chuvashia Intern. J. Environ. Sci. Educ. 11(17), 10651-9.
[5] Scomra U 2008 Genetic resources of hops in Poland: collection, evaluation and utilization in breeding Proceeding of the International Scientific Meeting. Chmelarsky Institute, Zatec. P. 13-8.
[6] Kofta I, Klapal J, Jezech Ticha J 2008 Hodnoceni kvalitativni ukazateluk ceskych chmelu ze skiznaze skizne (Chmelarsvti) pp 1-8.
[7] Seigner E, Lutz A and Seefelder S 2008 Utilization of genetic resources in breeding programmes at the Hop Research Center Huell Proceeding of the International Scientific Meeting. (Chmelarsky Institute, Zatec) pp 8-12.
[8] Fadeev A A and Nikonova Z A 2015 The results of the study of hop varieties of different groups
of ripeness on economically important traits and resistance to the main diseases Agrarian Sci. Euro-Northeast 5 (48) pp 29-33.

[9] Nikonova Z A and Korotkova Z P 2017 Creating and preserving a collection of common hops as a gene pool for breeding Niva Volga 4 (45) pp 104-8.

[10] Fadeev A A and Nikonova Z A 2018 Assessment of variety samples of the collection of common hops according to phenological and morphological features Bull. Russian Agricul. Sci. 2 pp 40-2.

[11] Danilova Y S 2008 Types of hops depending on the biochemical composition Agrarian Sci. Euro-Northeast 11 pp 51-6.

[12] Dresel M, Dunkel A and Hofmann T 2015 Sensomics analysis of key bitter compounds in the hard resin of hops (Humulus lupulus L.) and their contribution to the bitter profile of Pilsner-type beer. J. Agricul. Food Chem. T63 13 pp 3402-18.

[13] Efimov A D and Korotkov A V 2009 Productivity of hops depending on the timing and height of the cut stems when cutting the main rhizomes Agricul. Sci. Euro-North-East 3(14) pp 45-7.

[14] Korotkov A V 2015 Influence of atereffects of liming, fertilizers and green manure crops on the parameters of fertility of gray-forest heavy loamy soil and yield of hops Bull. Mari State Uni.. Series Agricult. Sci. Econ. 4 (4) pp 29-33.