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Honey-Bearing Potential of *Tilia cordata* Mill. Forests in the Southern Urals

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This article examined the honey-bearing potential of *Tilia cordata* Mill. stands in the Southern Urals using forest management and taxation methods. The studies were conducted in pure and mixed even- and uneven-aged forests with *T. cordata* Mill. in different natural zones of the Southern Urals on the territory of the Bashkirs. These were forests of the South Ural forest-steppe region, the forest-steppe region of the European part of Russia, the area of coniferous-deciduous (mixed) forests of the European part of Russia. The research employed the method of laying temporary and permanent trial areas. *T. cordata* Mill. forests on the republic's territory were divided into zones by forest districts. There is a discrepancy between the territorial localization of "nectar" (honey-bearing) linden and designated forest areas, that is, honey-bearing forest areas on the republic's territory. It could be due to the lacking methodology for assigning linden to these categories. The increased rotation age of linden trees to 81–90 years for several decades, a ban on final cutting, reduced annual cut of soft-leaved forests by 15% enlarged the stocks of overmature forest to 48%. Depending on the age, the number of flowers on one *T. cordata* Mill. tree varies from 0 to 60.2 thousand pieces. The maximum amount of nectar is 69.04 kg/ha at 12-day linden flowering. The honey productivity of plants including *T. cordata* Mill., calculated concerning the linden age, its share in the forest composition, the average number of flowers on the tree, nectar per 1 ha of linden and the flowering period ranged from 252.8 to 662.8 kg/ha.

Keywords: *Tilia cordata* Mill., beekeeping, honey productivity, bee colonies, nectar productivity, tree stand, composition of plantings

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INTRODUCTION

Forests are known to have unique flora and fauna. They are essential in providing numerous ecosystem functions and benefits, including nectar secretion (Bystriakova et al., 2018; Agbelemoge and Adekola, 2020; Cunningham-Minnick and Crist, 2020; Krishnan et al., 2020; Perennes et al., 2021). There are many definitions of ecosystem potential, for instance, the one proposed by Burkhard et al. (2012). It claims that the ecosystem potential is the ability to provide services due to natural factors (climate, relief, habitat, and vegetation) and human activities (land and forest management, industrial activities, etc.). The following definition better describes pollination services. The ecosystem potential is a service supply calculated for environmental conditions best for providing resources to the beekeeping industry while simultaneously meeting this type of ecosystem (Yumashev et al., 2016; Bosma et al., 2017; Häussler et al., 2017; Roberts et al., 2017; Affek, 2018; Samsonova et al., 2019).

A significant part of the potential natural honey-bearing resources in the Russia belongs to different categories of forest lands with numerous woody honey plants. The total forest area of the primary honey-bearing woody plants in Russia, including *Tilia cordata* Mill., *Acer platanoides* L., *Salix caprea* is 4,886 thousand ha, of which 67% are occupied by *T. cordata* Mill. stands. The Bashkirs is a leader in forest stocks with the dominant composition of *T. cordata* Mill., occupying 1.14 million ha of 5.7 million ha of forest lands. Mature and overmature linden stands cover 637.1 thousand hectares (55.9%), young plants – 72.2 thousand hectares (6.3%), with an average age of lime tree forests of 61.1 years. Russia fully meets domestic requirements for honey. Since 2014 it has become a net honey exporter, ranking 39th among other countries between Taiwan and Serbia. Nevertheless, the country's forest is often considered a source of timber and not a natural resource for bee-keeping products. In addition, there are available resources for the effective development of beekeeping in the republic, but there is still a problem in listing nectar lime tree forests on the inventory. Electronic card filing could improve the efficiency of nomadic beekeeping (Sokolov, 1983; Sultanova et al., 2017; Gabdelkhakov et al., 2021; Martynova et al., 2021).

There has been little discussion of forest use in beekeeping. The research in this field is at an early stage of development and, as a rule, presented by monographic studies. Studies are mainly devoted to higher timber and ecological efficiency of the forest, determined by its biomass or protective properties, the ability to compensate for man-made, recreational and other loads (Bürgi, 1999; Matula et al., 2012; Pukkala et al., 2014; Jacobsen et al., 2018; Konashova et al., 2018; Smith et al., 2019; Sultanova et al., 2019; Samburova et al., 2022). The lack of research in contemporary beekeeping has a significant impact on the distribution of hives over an area for better honey production. There is an urgent need to assess the honey-bearing potential of lime tree forests as a food supply for beekeeping, which will contribute to targeted farming in linden stands, higher yield of commercial honey and more bee colonies on the territory of the forest fund.

The given study aimed to investigate the honey-bearing potential of *T. cordata* Mill. stands in the Southern Urals using forest management and taxation methods.

The research objectives were to distribute *T. cordata* Mill. forests on the republic's territory by zones by forest districts; to analyze honey productivity of plantings including *T. cordata* Mill. taking into account the linden age, its share in the forest composition, the average number of flowers on the tree; to develop an information file of the honey-bearing potential of nectar linden trees of the Southern Urals.

MATERIALS AND METHODS

The research was conducted in pure and mixed even- and uneven-aged forests with *T. cordata* Mill. in different natural zones of the Southern Urals on the territory of the Bashkirs. These included forests of the South Ural forest-steppe region, the forest-steppe region of the European part of Russia, the area of coniferous-deciduous (mixed) forests of the European part of Russia. The study relied on the following initial data: the natural and climatic conditions of the Bashkirs, specially protected forest areas (honey-bearing forest areas). The *T. cordata* Mill. forests in the republic were divided into zones based on forest districts (**Figure 1**) as follows: zone I – linden trees occupy less than 100 ha; zone II – linden trees cover 100–15,000 ha; zone III – 15,000–55,000 ha; and zone IV – 55,000–115,000 ha. The linden area and stocks were classified as "nectar lime tree" by the rotation age of mature forest of 81–100 years old.

The research employed laying temporary and permanent trial sites under forestry standard OST 56-69-83 "Trial sites in forest management. Trial establishment." There were long-term observations and experimental work at the trial sites. The flowering of lime tree forests was studied in a permanent control trial area. All the trees there were numbered, their diameter, age class and average height for every diameter class were determined. The number of flowers was analyzed on sample trees in the north-south- and west-east-oriented crown direction. The crown was divided into 2-m segments. The flowering rate of *T. cordata* Mill. trees was determined by a 5-point scale of visual flowering evaluation: 0 – a total absence of flowers; 1 – flowers are available in the upper quarter of the crown; 2 – flowers are available in the upper half of the crown; 3 – flowers are available in three quarters of the crown; and 4 – flowers are available in the entire crown.

The undergrowth layer in the stands under examination: *Cerasus fruticosa (Pall)*, *Padus racemosa (Lam.) Gilib*, *Viburnum opulus* L., *Rosa acicularis Lindl*, *Rubus idaeus* L., *Lonicera xyloxteum*, *Coryllus avellana*, *Sorbus aucuparia* L. *Forest live cover: Aegopodium podagraria, Chamerion angustifolium, Heracleum sibiricum, Archangelica officinalis, Melilotus officinalis* L., *Polygonum alpinum*, *Achillea millefolium, Echinops sphaerocephalus* L., *Lavatera thuhngiaca* L., *Origanum vulgare* L., *Carduus crispus*.

The honey productivity of plantings including small-leaved linden was determined based on the stand density, age, the share of linden in the forest composition, the average number of flowers on a linden tree, the average amount of nectar per 1 ha of linden, the average linden flowering period according to the formula:

$$\mathrm{HP} = N \times \left(\frac{L}{10}\right) \times F \times S \tag{1}$$

where HP is the honey productivity of the linden on the plot; *L* is the linden coefficient in the forest composition (**Table 1**); *N* is the amount of nectar per 1 ha based on the stand density; *F* is the linden flowering time; *S* is the area of the plot, ha.

This can be illustrated by a forest stand of a high density (0.8) with a composition of 8NTC2B + A. growing on an area of 10 ha. Honey productivity for an average linden flowering period of

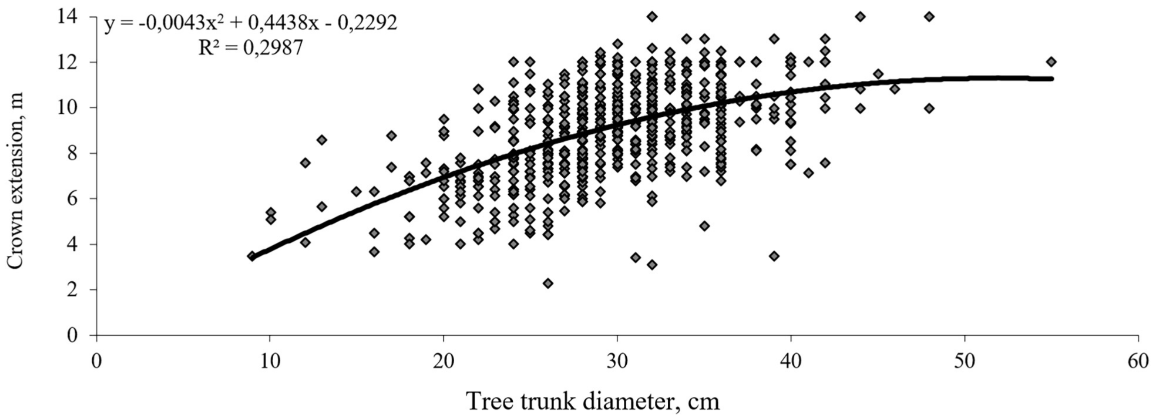

FIGURE 1 | Dependence of the crown extension on the linden trunk diameter (41–60 years old).

12 days is calculated as follows based on the Murakhtanov (1977) dynamics of average nectar-bearing capacity indicators and field studies of the present research:

$$HP = 69.04 \times \left(\frac{8}{10}\right) \times 12 \times 10 = 6,627.8 \text{ kg}$$

Nectar from linden flowers was extracted by rinsing. Fifty flowers had been collected from the southern and northern sides of the crown and placed in a glass flask. Then the flask was poured with an accurately measured amount of distilled water. The flask with flowers and a distiller was clogged. shaken for 20–30 min. Next. the flask contents were to be filtered and 20 cm^3 filtrate drained into a vessel for examination. This method of studying the amount of nectar in flowers requires strict isolation of flowers from bees and other insects. Four samples during the flowering of the lime tree are sufficient to conduct an analysis (Murakhtanov, 1977). The data were processed using variational statistics. correlation and regression analysis. Microsoft Excel and Statistica 6.0 programs.

RESULTS

Considering the high value of linden trees as honey plants, their felling was limited in the Bashkirs since late 1950s. Lime trees were protected for the sake of beekeeping legislatively. including resolutions of the Bashkir Republic's Council of Ministers No. 693 "On measures for farming in lime stands located in the area of developed beekeeping" dated October 01, 1959 and No. 347 "On measures to develop beekeeping and increase honey production" dated July 30, 1968. The cutting of *T. cordata* Mill. for harvesting wood in 3-km zones around beekeeping apiaries and in areas of developed beekeeping was banned in more than 80% of the forest area. These regulations along with the "Logging rules for lime tree forests in the zone of stationary apiaries" caused a sharp drop in the volume of harvested wood from 1994 to 2004. The estimated cutting area reduced from 42.1 in 1991 to 11.7% in 2002. Large amounts of merchantable wood underused until 2004 resulted in accumulation of ripe and overmature *T. cordata* Mill. forests. Ripe and overgrown forests still prevail though cutting of *T. cordata* Mill. increased from 168.0 to 262.0 thousand m^3 in 2017–2019. This fact has both positive and negative impacts. Ripening and mature stands have more inflorescences and nectar per one tree. The nectar yield from one flower of a 50-year-old *T. cordata* Mill. sample tree amounted 0.944 $\pm$ 0.351 mg while it was 1.402 $\pm$ 0.112 mg from a flower of 100–year-old trees. The nectar production is reducing in the years following. The crown extension (south-north) in the conditions of the research area affects the flowering intensity: 60–70-year-old trees have 36,960 inflorescences on the south side and 30,310 flowers on the north side. The flowering rate is more dependent on the crown height. The top of the crown produces from 30 to 59% inflorescences of the total while the middle part from 31 to 49% flowers. At the base of the crown there are from 4 to 21% of inflorescences. With age, the flowering production ratio in different parts of the crown does not change significantly. The observed significant differences in the inflorescence number depending on age (r = 0.96; S_r = 0.04) are not confirmed by the reliable differences in honey-producing characteristics: the sugar-in-solution concentration (max 16.4 $\pm$ 1.1; min 11.8 $\pm$ 1.3%). nectar-forming capacity (max 0.656 $\pm$ 0.21; min 0.472 $\pm$ 0.08 mg). nectar bearing capacity (max 1.312 $\pm$ 0.092; min 0.944 $\pm$ 0.351 mg) and honey productivity (max 0.82 $\pm$ 0.05; min 0.59 $\pm$ 0.07 mg). The maximum and minimum values are common both for middle-aged and overripe stands.

Small-leaved linden has a powerful crown with the diameter variation coefficient up to 42.2%. There is a close relationship between the crown extension and the trunk diameter expressed by the correlation coefficient r = 0.547 (**Figure 1**). The intensity of flowering and fruiting is closely related to the crown diameter (**Figure 2**).

Several factors make nectar-bearing forests in the Southern Urals attractive: sustainable growth of external and internal demand for beekeeping products; sufficient amount of available nectar-bearing plants; free access to forest resources under the provisions of the state forest policy; comprehensive state support and constant attention of the government to beekeeping as one of the essential branches of agriculture; implemented investment

TABLE 1 | Honey productivity of *Tilia cordata* Mill. depending on the stand density (Murakhtanov, 1977).

Age, years	High density (1.0–0.9)				
	The number of trees per 1 ha, pcs.	The average amount under single observation			
		Flowers per I tree, thousand pieces	Nectar		
			Per 1 flower, mg	Per 1 tree, g	Per 1 ha, kg
20	3,840	1.5	1.12	1.68	6.45
30	2,752	7.2	1.42	10.22	28.12
40	1,958	13.1	1.69	22.14	43.35
50	1,510	18.8	1.87	35.16	53.09
60	1,219	24.5	2.06	50.47	61.52
70	1,000	30.2	2.20	66.44	66.44
80	849	34.9	2.33	81.32	69.04
90	728	38.3	2.41	92.30	67.29
100	629	39.5	2.50	98.75	62.11
110	547	40.1	2.53	101.45	55.49
120	477	39.9	2.56	102.14	48.72
130	418	38.3	2.58	98.81	41.30
Average density (0.8–0.7)					
20	2,987	1.7	1.23	2.09	6.24
30	2,141	8.3	1.56	12.95	27.73
40	1,523	15.0	1.86	27.90	42.49
50	1,175	21.5	2.06	44.29	52.04
60	948	28.0	2.27	63.56	60.25
70	778	34.6	2.42	83.73	65.14
80	660	39.8	2.56	101.89	67.25
90	567	43.9	2.65	116.33	65.96
100	489	45.1	2.75	124.02	60.65
110	426	45.8	2.78	127.32	54.24
120	371	45.6	2.82	128.58	47.71
130	325	43.8	2.84	124.39	40.43
Low density (0.6–0.4)					
20	1,707	2.2	1.34	2.95	5.04
30	1,223	11.0	1.70	18.70	22.87
40	870	20.0	2.03	40.60	35.32
50	671	28.6	2.24	64.06	42.98
60	542	37.3	2.47	92.13	49.93
70	444	46.1	2.64	121.70	54.03
80	377	53.1	2.80	148.68	56.05
90	324	58.2	2.89	168.20	54.50
100	280	60.2	3.00	180.60	50.57
110	243	61.1	3.04	185.74	45.13
120	212	60.8	3.07	186.66	39.57
130	186	58.4	3.10	181.04	33.67

projects and provided business benefits. Meeting the growing demand of the population for organic beekeeping products requires the expanded nectar-bearing base and identifying forests as a primary component in the production system of the beekeeping industry.

The most common subspecies of bees for the South Ural region on the territory of the Bashkortostan Republic is the Burzyan honey bee *Apis mellifera mellifera*. It is resistant to invasive diseases and aggressiveness, being an important factor for preventing infections and preserving the population. In addition, it has high resistance to cold, it can collect honey actively and in the short run. Bees are locally preserved in the mountain-forest zone in the state nature reserve "Shulgan-Tash," the Altyn Solok Nature Reserve and the Bashkiria National Park. Though wild-honey farming has been a traditional occupation of Bashkirs, 99% of the Burzian *A. mellifera mellifera* are kept in apiaries with frame hives. About 1% bees live in natural and artificial hollows in tree trunks – boards and decks.

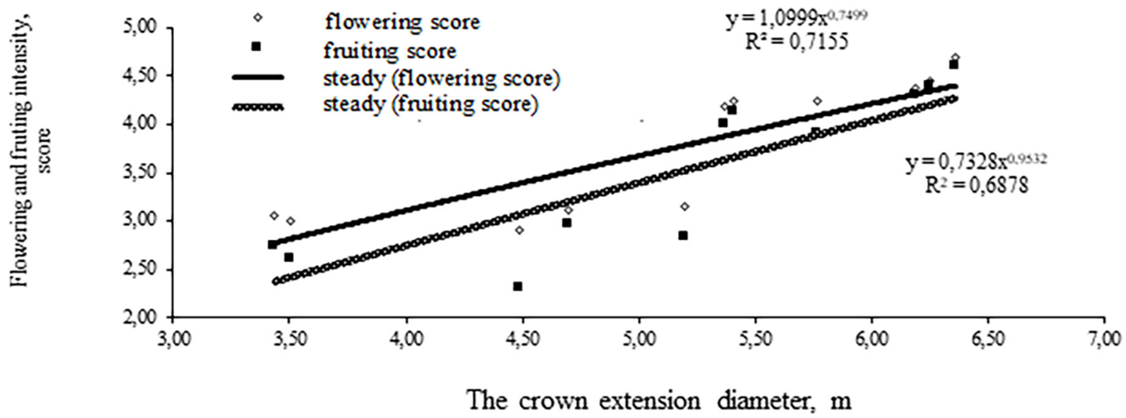

FIGURE 2 | Dependence of tree flowering and fruiting on its crown diameter.

The potential honey-bearing resources. including the unique linden stands of *T. cordata* Mill. differing in structure. distribution scale. reproduction and honey productivity. are distributed unevenly across the natural zones of the region. Depending on natural zones. climatic conditions and landscape. the size of honey-bearing resources range from complete absence to 107.7 thousand ha. Linden in several forest districts located in the south-eastern part of the republic does not grow or occupies an area of less than 100 ha with a total reserve of about 1 thousand m^3. It grows to a greater extent in the central. southern and western regions of Bashkortostan: Arkhangelskoe (18,377.4 thousand m^3). Gafuriiskoye (20,910.9 thousand m^3). Iglinskoie. Makarovskoie. Nurimanovskoie. Ufa forestry districts. where it occupies up to 50% of the total forested area. The flowering time and duration. honey harvest conditions are also different. Some climatic factors "shift" the beginning of *T. cordata* Mill. flowering and its duration. Based on the timing of linden flowering. three zones are identified that are comparable to the average annual isotherms of the republic's territories and the spread of linden trees throughout the region (**Figure 3**).

With an increase in the average annual temperature. the *T. cordata* Mill. flowering starts earlier ($r = -0.5$ at $S_r = 0.12$. $t_r = 4.08$. $t_{0.05} = 2.01$). The sum of temperatures for April–September also affects the annual volume of honey from one bee family ($r = 0.51$. $F = 0.69$).

Zone (I) is the area of the earliest flowering of *T. cordata* Mill. Linden trees make up the largest and the average share in the forest compositions (from 15,000 to 115,000 ha. **Figure 4**). It has the highest average annual air temperature of 2.0–2.5°C. The flowering begins on June 25. The intermediate flowering zone (II) is on the territory with the average annual isotherm of 1.5–2.0°C. The average date of flowering is July 1. The late flowering zone (III) is characterized by the lowest average air temperature up to 0.5°C. Flowering starts on July 10. There is the smallest number of linden trees.

In total. *T. cordata* Mill. stands referred to as the economic section "nectar linden." and being the melliferous sources of the region. occupy an area of 157.7 thousand ha with a total wood stock of 29 thousand m^3 (**Figure 5**).

Honey-bearing areas of forests are distinguished as specially protected areas (SPA) in stands with a predominance of maturing. mature and overmature *T. cordata* Mill. trees. They adjoin the 3-km zone around apiaries with a special farming mode. SPAs can be allocated in protective. operational and reserve forests. Linden trees in honey-bearing areas of forests around stationary apiaries are mostly cut because of not being included in the SPA category. The SPA legal status protects the linden trees from logging. which contributes to their preservation.

The development of beekeeping depends on the knowledge of the forage base. The specific. qualitative. quantitative and territorial representation of forest honey-bearing plants is a decisive factor when choosing places for the apiary. The available data characterizing forest melliferous resources make it possible to solve the following tasks: to determine the potential honey productivity of forests; to choose the most suitable place for apiaries; to determine the optimal number of bee colonies; to set the timing of honey flows and their duration; to develop a system of forestry management measures for nectar-bearing plants.

To address uneven distribution of melliferous sources and the resulting competition between bee colonies for food, it is necessary to compile an inventory of honey-bearing lands and ensuring twofold migration of bees from forests to fields planted with honey crops during the entire honey harvest season. It can increase the number of bee colonies in small apiaries up to 150, providing one bee family (50–60 thousand bees) with at least 130 kg of nectar. Meanwhile, it should be taken into account that 1 ha of forest, depending on forestry and taxation indicators, can produce from 500–700 to 150–200 kg of nectar.

Based on the above mentioned. an information file of the honey-bearing potential of nectar lime tree forests in the Southern Urals was developed. **Table 2** presents a fragment of the card file for mixed deciduous plantings of 34 allotments in six quarters of the Iglinskii forestry district on an area of 278.5 ha. The *T. cordata* Mill. composition here ranges from five to eight units. In addition. the stands include *Betula pendula* Roth. *Quercus robur* L. and *P. racemosa* Lam. Gilib. *S. aucuparia* L. Depending on the age. the number of flowers on one *T. cordata*

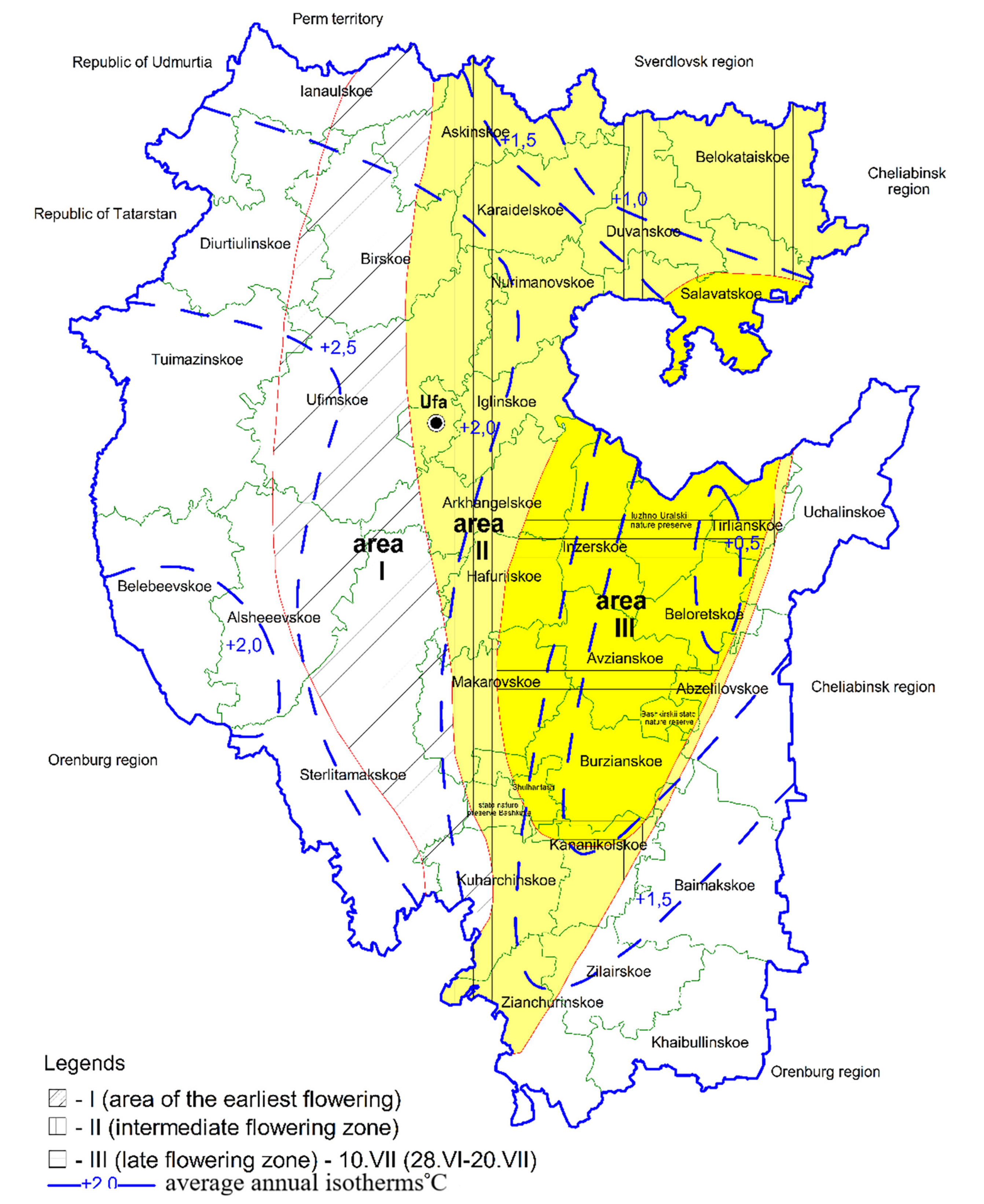

FIGURE 3 | Phenological zones according to the timing of linden flowering.

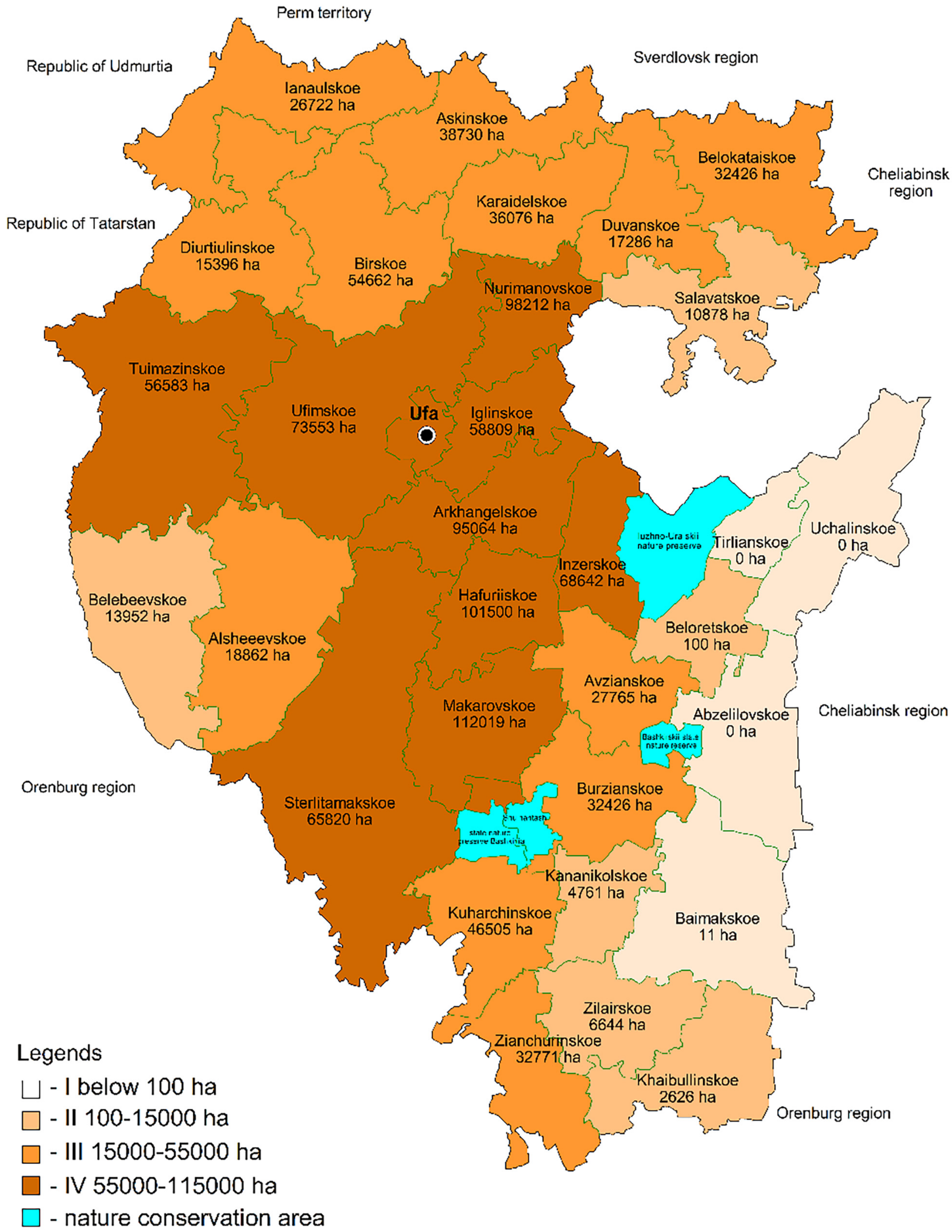

FIGURE 4 | Zoning of forest districts by the presence of lime trees in the forest composition.

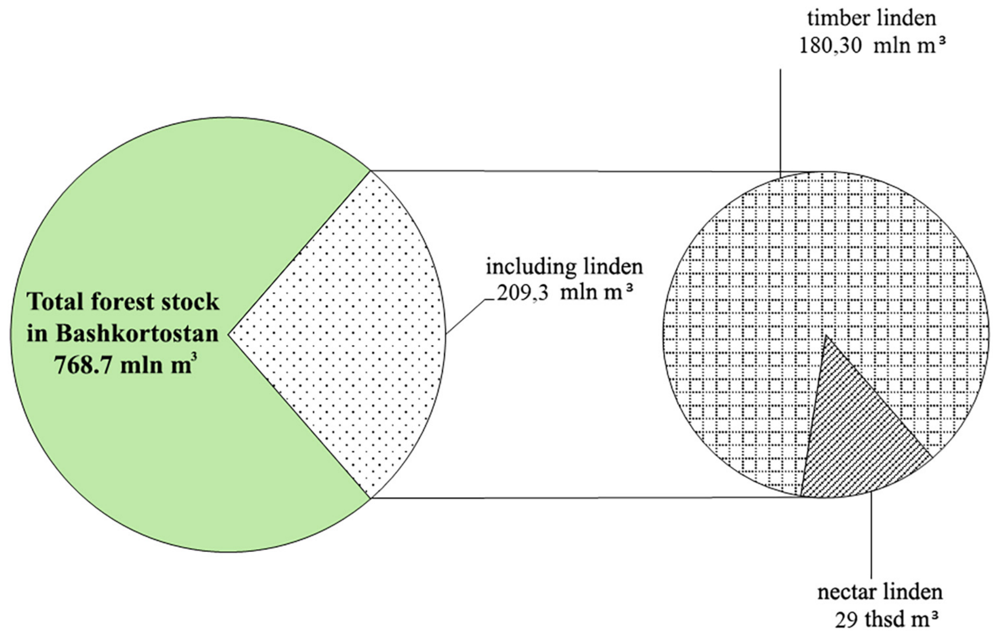

FIGURE 5 | Distribution of the total *Tilia cordata* Mill. wood stock by economic sections – commercial linden and nectar linden.

Mill. tree varies from 0 to 60.2 thousand pieces. The maximum amount of nectar is 69.04 kg/ha at 12-day linden flowering.

The honey productivity of plants including *T. cordata* Mill. calculated concerning the linden age. its share in the forest composition. the average number of flowers on the tree. nectar per 1 ha of linden and the flowering period ranged from 252.8 to 662.8 kg/ha.

DISCUSSION

Polish scientists found that there are 32 species of honey-bearing plants out of 85 plant species growing in 51 phytosociological regions. They are the food base for bees. The researchers distinguished forest plants with the highest honey-bearing capacity: *Scrophularia nodosa* L. (up to 700 kg/ha) and *Solidago gigantea* Aiton (700 kg/ha). The latter is an introduced species in these forests. The group of plants with a high honey-bearing potential (more than 100 kg/ha) also includes *Angelica archangelica*. *Stachys sylvatica* L. *Aronia melanocarpa*. *Ajuga reptans* L. *R. idaeus* L. *T. cordata* Mill. and *A. platanoides* L. They have a wide ecological growth amplitude and can grow in moist habitats (Affek et al., 2021). The honey production potential of some species of honey-bearing plants. having no quantitative data in the literature. was estimated based on the calculation of the nectar bearing capacity of similar species (Szklanowska, 1979).

Numerous botanical studies of honey have revealed the dominance of forest tree species as the main food supply for beekeeping (Elzaki and Tian, 2020). The authors showed that the botanical origin of honey influences its marketing in Sudan and most Arab countries. Honey from the *Ziziphus spina-christi* L. Desf. and *Acacia nilotica* L. Delile nectar is especially appealing to many consumers.

For example. in Sudan. the maximum density of hives is 10. 8. 7 and 8 per hectare for *Acacia seyal. A. nilotica. Z. spina-Christi and Eucalyptus* spp., respectively. This result shows a very low number of hives per hectare compared to Ethiopia. where about 0.03 hectares are required for every three hives (Jenkins and Miklyaev, 2014). Meanwhile it is higher than in Saudi Arabia with one hive per two hectares (Al-Ghamdi et al., 2016). The authors indicate two reasons for the low yield of honey in Sudan and most Arab countries: the lack of experience in managing modern beekeeping for optimal honey production and the lower bee feed quality.

Tilia cordata Mill. is essential in adapting forests to climate change due to the wide environmental sustainability and more ecosystem opportunities (De Jaegere et al., 2016). including food supply for beekeeping. This study found irregular distribution of melliferous sources. resulting in competition between the bee colonies for food resources that is consistent with findings of other researchers. Honey-bearing plants are distributed unevenly in the natural environment. It has an impact on the density of hives (Torné-Noguera et al., 2014); the area of honey plants is changing dramatically throughout the season and from year to year (Flo et al., 2018).

Comparing the calculated honey productivity potential with the corresponding apiary's demand for nectar during the flowering period of the linden tree draws to the conclusion on the possible number of bee colonies on the territory. *T. cordata* Mill. honey-bearing lands on the area of 157.716 ha classified as the economic category "nectar linden" make it possible to place up to 1,261.7 thousand bee colonies based on the density of 8 bee colonies per 1 ha.

TABLE 2 | Honey-bearing potential of specially protected areas (SPA) – "honey-bearing forest areas" (fragment). Object: Iglinskoe. Ulu-Teliakskoe forest districts.

Location of the forest plot		Area. ha	Taxation characteristics of the plantation (wood stock. undergrowth. understorey)							Honey-bearing potential				
Sq. No.	Allot.No.		Composition	Age. years	Growth class	Density	Reserve. m^3/ha	Understorey. density	Species composition of undergrowth. age (years). height (m). quantity (thousand pieces/ha). condition	Share of *Tilia cordata* Mill. in the composition of the forest stand.% stock*	Number of flowers on 1 linden tree. thousand pcs.*	Amount of nectar per 1 ha of lime. kg*	Linden flowering time. days*	Honey productivity of lime tree. kg
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
162	1	48.00	5NTC1TC2UG1QR1AP	80	3	0.6	210	thin PA	6UG2AP2TC (12) 3.0 m. 1.5 thousand pcs/ha.UGll affected	60	39.8	67.25	12	23,242
162	2	49.10	5NTC2TC1UG1QR1AP	75	3	0.6	210	thin PA	6UG2AP2TC (12) 3.0 m. 1.5 thousand pcs/ha.UGll affected	70	37.2	66.2	12	27,304
162	3	27.90	5NTC2TC1BP1UG1QR	75	3	0.6	230	thin PA	5TC3UG2AP (12) 3.0 m. 2.0 thousand pcs/ha. UGll affected	70	37.2	66.2	12	15,515
180	6	8.00	6NTC2BP1UG1QR	60	3	0.7	270	thin PA		60	28	60.65	12	3,493.4
180	8	2.20	4NTC3BP2UG1QR+PT	60	3	0.7	270	thin PA		40	28	60.65	12	640.46
180	10	10.20	8NTC1UG1BP+QR	75	3	0.6	230	thin PA		80	37.2	66.2	12	6,482.3
180	11	3.90	8NTC1UG1U	65	3	0.6	210	thin PA		80	31.3	62.7	12	2,347.5
180	12	0.30	5NTC2BP2PT1UG	75	3	0.6	190	thin PA		50	37.2	66.2	12	119.16
180	14	3.10	8NTC1UG1U+PT+QR	65	3	0.7	250	thin PA		80	31.3	62.7	12	1,866
294	8	1.20	5NTC3UG1PT1AP	35	3	0.7	130	thin PA		50	11.65	35.11	12	252.79
294	10	5.40	5NTC2PT2U1UG	35	3	0.7	130	thin PA		50	11.65	35.11	12	1,137.6
295	2	13.60	3NTC2TC2PT2UG1QR	90	3	0.6	260	PA SA Average		50	43.9	65.96	12	5,382.3
295	5	6.10	5NTC3PT1BP1U	40	2	0.8	210	CR medium		50	13.1	43.35	12	1,586.6
295	9	5.10	5NTC2TC2BP1PT+UG	100	3	0.6	260	PA R Average	8TC2UG (20) 3.0 m. 4.0 thousand pcs/ha. UGll affected	70	45.1	60.65	12	2,598.2
295	10	0.70	8NTC2UG	10	3	0.7	20			80	0	0	12	0
296	5	5.60	6NTC3BP1PT+UG	85	3	0.8	380	thin PA	6TC4UG (10) 3.0 m. 2.0 thousand pcs/ha. UGll affected	60	36.6	68.16	12	2,748.2
296	7	7.30	6NTC2TC2BP+PT	95	3	0.8	350	thin PA	6UG4TC (20) 5.0 m. 3.5 thousand pcs/ha. UGll affected	80	38.9	64.7	12	4,534.2
296	8	2.00	6NTC2PT2BP+U	35	3	0.7	130			60	11.65	35.11	12	505.58
296	9	6.10	4NTC3TC3BP+PT+UG	100	3	0.7	330	thin PA	8U2TC (15) 5.0 m. 3.0 thousand pcs/ha. UGll affected	70	45.1	60.65	12	3,107.7
296	12	11.30	6NTC2PT2UG+TC	35	3	0.7	130	CR medium		60	11.65	35.11	12	2,856.5
296	14	2.90	6NTC2PT2BP+UG	40	3	0.7	150	thin PA		60	15	42.49	12	887.19

(Continued)

TABLE 2 | (Continued)

Location of the forest plot		Area. ha	Taxation characteristics of the plantation (wood stock. undergrowth. understorey)							Honey-bearing potential				
Sq. No.	Allot.No.		Composition	Age. years	Growth class	Density	Reserve. m^3/ha	Understorey. density	Species composition of undergrowth. age (years). height (m). quantity (thousand pieces/ha). condition	Share of *Tilia cordata* Mill. in the composition of the forest stand.% stock*	Number of flowers on 1 linden tree. thousand pcs.*	Amount of nectar per 1 ha of lime. kg*	Linden flowering time. days*	Honey productivity of lime tree. kg
296	15	10.00	8NTC2BP+PT	80	2	0.8	380	thin PA	6TC4UG (20) 5.0 m. 4.0 thousand pcs/ha. UGll affected	80	34.9	69.04	12	6,627.8
297	28	1.40	6NTC2BP2PT+UG	100	3	0.5	210	PA SA Average	6TC2U2AP (15) 2.0 m. 2.0 thousand pcs/ha. UGll affected	60	60.2	50.57	12	509.75
297	29	3.10	6NTC3BP1PT+UG	90	3	0.6	250	thin PA	6TC2U2AP (20) 2.0 m. 3.0 thousand pcs/ha. UGll affected	60	43.9	65.96	12	1,472.2
297	31	6.40	5NTC5BP+PT+UG	90	3	0.6	260	PA SA Average	5TC3U2AP (20) 2.0 m. 2.0 thousand pcs/ha. UGll affected	50	43.9	65.96	12	2,532.9
297	34	0.60	5NTC3BP2U	30	3	0.6	100	GW PA average		50	8.3	27.73	12	99.828
297	43	1.90	6NTC3BP1PT+UG	100	3	0.5	220	CR medium	6TC2AP2U (30) 3.0 m. 3.0 thousand pcs/ha. UGll affected	60	60.2	50.57	12	691.8
297	2	1.90	5NTC1TC3BP1PT	100	3	0.5	220	CR medium	5TC4U1AP (25) 2.5 m. 3.0 thousand pcs/ha. UGll affected	60	60.2	50.57	12	691.8
297	4	16.00	5NTC2BP2PT1UG	85	3	0.6	250	PA SA Average	6TC3U1UG (20) 2.0 m. 3.0 thousand pcs/ha. UGll affected	50	41.85	66.6	12	6,393.6
297	6	4.60	6NTC3UG1BP+PT	25	3	0.7	80	PA SA Average		60	5	16.98	12	562.38
297	15	5.40	7NTC2BP1PT+QR+UG	90	3	0.6	250			70	43.9	65.96	12	2,991.9
297	18	1.80	5NTC5BP+PT+UG	90	3	0.6	260	thin PA	6TC4AP (10) 2.0 m. 2.0 thousand pcs/ha. UGll affected	50	43.9	65.96	12	712.37
297	24	2.40	5NTC2TC2BP1PT+UG	90	3	0.5	190	PA medium	6TC3AP1U (20) 2.0 m. 2.0 thousand pcs/ha. UGll affected	70	58.2	54.5	12	1,098.7
297	45	3.00	6NTC2BP2PT+UG	90	3	0.5	220	thin PA	4TC3AP3U (20) 2.0 m. 2.0 thousand pcs/ha. UGll affected	60	58.2	54.5	12	1,177.2

The numerical data (columns 12–15) for calculating the honey productivity of linden (column 16) are taken according to Murakhtanov (1977).
Abbreviations of tree species: NTC, nectar Tilia cordata Mill.; TC, Tilia cordata Mill.; BP, Betula pendula Roth; UG, Ulmus glabra Huds; QR, Quercus robur L.; AP, Acer platanoides L.; PT, Populus tremula L.; U, Ulmus L. Undergrowth; PA, Padus avium Mill.; and SA, Sorbus aucuparia L.

CONCLUSION

In forest stands with the prevailing linden composition. it is advisable to farm linden. create target conditions for its growth and use its nectar qualities for beekeeping.

1. The republic's high potential in the beekeeping industry development is determined by the available honey-bearing resources of small-leaved linden. The difference in its volume across the region is enormous. There are no linden trees in the southeastern part (Abzelilovskoe. Uchalinskoe. Tirlianskoe forestry districts) while lime trees are abundant in the central. southern and western parts (Gafuriiskoe. Iglinskoe. Nurimanovskoe. Ufimskoe. Arkhangelskoe forest districts. where linden occupies up to 50% of the area covered by forest). For example. the lime tree takes up more than 112 thousand ha in the Makarovskoe forestry district.
2. The small-leaved linden's flowering time and duration. the conditions of the honey collection are different and depend on natural zones. climatic conditions. differ. In this regard. it was entirely justified to assess the development rate of forest territories for beekeeping activities. It is not well developed. There are 991 forest plots on 1,059.5 ha.
3. There is a discrepancy between the territorial localization of "nectar" (honey-bearing) linden and specially protected honey-bearing forest areas on the republic's territory. There is no developed methodology for assigning linden to these categories. The Russian national forest register does not distinguish between "commercial linden" and "nectar linden" (honey-bearing). It complicates the procedure for allocating plots for apiaries on forest fund lands.
4. The increased rotation age of linden trees to 81–90 years for several decades. a ban on final cutting. reduced annual cut of soft-leaved forests by 15% enlarged the stocks of overmature forest to 48%. Taking into account the age limit of *T. cordata* Mill., a source of high-quality lime honey, the set of measures should include logging of ripe *T. cordata* Mill. stands and regeneration cut of overripe trees losing their target functions to promote natural renewal and favorable conditions to grow for the younger generation of *T. cordata* Mill.

The linden honey production card file will contribute to the development of industrial beekeeping in the Bashkirs. Both nomadic and stationary beekeeping can increase the forest food supply potential to 60–70% and enlarge honey production by 20–25%.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

RiS: conceptualization, validation, investigation, data curation, writing – original draft, review and editing, and visualization. MM: methodology, formal analysis, investigation, data curation, visualization, and writing – review and editing. ReS: conceptualization, methodology, resources, and writing – original draft, review and editing. All authors contributed to the article and approved the submitted version.

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