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Agrobiological Basis For Formation Of Crambe Abyssinica Agrocoenosis In Conditions Of Middle Volga.

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ABSTRACT

Agrobiological bases of crambe abyssinica agrocoenosis formation was studied for obtaining consistent productivity of oilseeds in different agroclimatic conditions. Weather conditions during the years of study were characterized as arid (HTC – 0.7), insufficiently moisturized (HTC – 0.9) and moderately moisturized (HTC – 1.1). In Middle Volga crambe abyssinica is a short-season crop with a short vegetation period of 93-107 days. In the result of mathematical analysis it was stated that the duration of vegetation period positively correlated with the air temperature (r=0.81) and with HTC (r=0.86). On average, for three years the field emergence rate of crambe seeds was relatively high and varied within the range 72.1-78.7 %, the preservation of plants by the harvesting made up 84.5 – 88.6 %. Maximum leaf-area duration of 65.7-72.5 thousand m^2/ha was observed in the phase of budding-blooming, photosynthetic potential made up 1.94 million m^2×day /ha. Net photosynthesis productivity didn't vary significantly from year to year and stayed within the range of 2.49-2.71 g/m^2×day. The yield of crambe abyssinica significantly changed depending on the annual hydrothermic conditions and fluctuated in average from 2.29 to 2.72 t/ha. High yield has formed in 2016 at favorable combination of temperatures and moisture regime (HTC – 1.1), but it didn't exceed the productivity of the crop in 2015 drastically (at HTC – 0.9), only by 0,03 t/ha. Oil content of crambe made up 42.6 – 43.8%, yield of oil was in average 0.98 t/ha. The formation of yield is greatly influenced by the number of pods on the plant, the influence percent of it is 38.9%. The influence percent of the productivity of an individual plant and the weight of 1000 seeds was 34.3 and 26.8%, respectively. In the fatty acid composition of the crambe oilseeds, a significant part falls on erucic acid, the content of which reaches 58.9%, which makes it possible to use this crop to produce biodiesel fuel.

Keywords: crambe abyssinica, vegetation period, photosynthesis activity, oil content, yield, fatty acid composition

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INTRODUCTION

During the growth and development the plants are exposed to different environmental factors, among them are temperature and moistening. Meanwhile, each plant has a genotypic ability to adapt in changing habitat conditions. It is the basic acclimatization element of the new crop in various agroecological conditions and large-scale implementation of crops into production. [1].

Crambe abyssinica Hochst. is a promising, rare oil crop of the Brassicaceae family with high productivity and adaptability potential. It is characterized by high processability of cultivation. This crop is annual, unpretentious for soil, short-rain, multipurpose with high seed yield (up to 3.0 t/ha) and high oil content (up to 46%) [2,3,4].

Due to low iodine number (86-97) in crambe oil it is easily refined and used in food industry. Its edible quality resembles one of white mustard oil and is used in confectionary industry, as a salad oil or for producing mayonnaise and margarine [5,6,7]. This oil is used in for making plastic films and plastic material, resins and lubricants in chemical and paint-and-varnish industries. Due to high content of eructic acid (up to 60%) crambe seed oil is a promising source of biodiesel fuel [8,9]. In medicine and perfumery the oil serves as an ingredient in moisturizing and nourishing facial and body creams and also for making shampoos and balms [10]. Seed cake containing up to 40% of protein and up to 35% of carbs is included into all-mash, the topsoil noted for its high yield of 2.0-2.1 t/ha is used for making haylage and silage. Being a good phytosanitary agent crambe is successfully grown as a green manure crop [11,12,13].

Due to its economically valuable characteristics, today the crambe abyssinica passes from the "experimental" to the "interesting" category to agricultural producers, both economically and agronomically, as an alternative to traditional oilseed crops. Therefore, the study of the agrobiological basis for the agrocoenosis formation of this crop in various agroclimatic conditions is a trending topic.

The objective of our studies is the evaluation of growth development pattern of crambe abyssinica and formation of agrocoenosis that provides stable oilseed productivity.

MATERIALS AND METHODS

Experimental work was conducted in 2015-2017 on the experimental field of 1FSBSI Penza Research Institute of Agriculture. The soil on the experimental area is leached black earth with humus content in topsoil up to 6.5%. All calculations, observations and analysis were conducted according to methodical recommendations on growing oil-bearing crops [14].

Meteorological conditions of crambe vegetation period in 2015 were quite favorable and characterized by the moderate moistening – HTC was 0.9 with the sum of active temperatures of 2046.3°C. Critical period of plant growth and development which is shoots-budding was also running in the conditions of moderate moistening (HTC – 1.1). During the period of budding-blossoming the rate of precipitation was exceeded by 3 times at mean daily temperature level mean annual data – 19.5°C. Crambe vegetation period in 2016 also ran in the conditions of moderate moistening (HTC – 1.1) at quite high mean daily temperatures (18.7°C). Precipitation in April 2017 (31.2 mm) provided a good supply of moisture in the soil by the moment of crops sowing, that is why the lack of precipitations in May didn't affect shoots and the period from shooting to blossoming ran in the conditions of moderate moistening (HTC – 1.0) with the sum of effective temperatures of 743.8°C. In whole the vegetation period in 2017 was marked by not sufficient moistening (HTC – 0.7) at mean daily temperature of 17.6°C and sum of active temperatures of 1995.3°C.

The Experimental Part

It is known, that each plant represents the integral morphogenetic structure with its peculiarities of growth, organs and productivity formation on each development stage where natural changes take place: seeds sprouting, growth of vegetation organs, blossoming and fructification in certain conditions of environment [1,7].

For years of study meteorological conditions of seasons greatly influenced crambe growth and development, this mostly defined the duration of interphase period and total vegetation period of the crop. Thus, in favorable conditions of 2016-2017 the shoots appeared in 8-9 days, in arid conditions in 2015 they appeared only in 12 days (table 1)

Table 1: Phenological phases of crambe abyssinica development (2015-2017)

Phenological phases	Number of days	Average air t, °C	∑ of effective t > 10°C	∑ of precipitations, mm	HTC
Sowing-shoots	8-12	12.3-14.2	125.1-148.6	0.0-8.3	0.0-1.0
Shoots-blossoming	46-58	14.6-18.3	743.8-935.2	89.9-132.5	0.9-1.8
Blossoming-ripeness	47-49	21.2-25.3	874.8-1114.5	71.9-158.6	0.8-1.1
Shoots-ripeness	93-107	17.6-22.2	1793.6-2046.3	147.8-214.3	0.7-1.1

The period from shoots to blossoming of crambe lasted from 45 to 58 days and ran in moderate (HTC – 0.9) and over-moisturized conditions (HTC – 1.8). Meanwhile, the shortest shoots-blossoming period was noted in 2015 at mean daily temperature of 18.3°C. Sum of effective temperatures for this period varied from 743.8 to 935.2°C.

Duration of blossoming-ripeness period for years of studies didn't differ significantly and made up 47-49 days. Crambe ripening started in the 3rd decade of July and ended in the 1st decade of August and ran in favorable conditions with HTC-0.8-1.1 and sum of effective temperatures 874.8-1114.5°C.

In whole, in the conditions of Middle Volga, crambe abyssinica is a fast-ripening crop with short vegetation period of 93-107 days.

As a result of mathematical analysis it was stated that the duration of vegetation period positively correlated with the air temperature (r=0.81) and with HTC (r=0.86).

For acquiring high yield of crambe it is necessary to form crops with optimal density of productive plant stand which is determined by field emergence and preservation of plants for harvest. In average for 3 years field emergence of crambe seeds was fairly high and varied within the range of 72.1-78.7 %. The lowest field emergence was witnessed in 2017 at zero value of HTC during the phase of sowing-shoots. Field emergence tended to increase by 4.8 – 6.6% during the more favorable years in respect to moistening (2015 and 2016) at HTC – 0.8-1.0. Plant preservation for harvest made up from 84.5 to 88.6 %. The highest values were marked in 2016.

One of the main factors, characterizing the state of crambe agrocoenosis is photosynthesis activity of plants during vegetation. During the crown phase leaf0area duration made up only 20.4-21.3 thousand m^2/ha. Intensive development of leaf apparatus started to be evident from budding phase and up to blossoming when it reached its maximum value – 65.7-72.5 thousand m^2/ha (table 2). After reaching the maximum values, assimilating surface "works" or different period of time increasing total photosynthesis potential of crops. Starting from fructification and until the full ripeness the plants start to lose leafs and total functional area reduces by 25.5 – 30.3%.

Table 2: Values of photosynthesis activity of crambe abyssinica

Value	2015	2016	2017	Average
Maximum leaf-area, thousand m^2/ha	68.6	72.5	65.7	68.9
Photosynthesis potential, million m^2×day /ha	1.98	2.11	1.76	1.94
Net photosynthesis productivity, g/m^2×day	2.56	2.71	2.49	2.55
Total receipt of PhAR during vegetation period, kJ/cm^2	92.8	93.1	90.9	92.3

Photosynthesis potential varied from year to year from 1.76 to 2.11 million m^2×day /ha and in average for 3 years it made up 1.94 million m^2×day /ha. Net photosynthesis productivity of crambe didn't differ significantly from year to year and stayed within the range of 2.49-2.71 g/m^2×day and the lowest values were noted in 2017, when the crops productivity was decreased because the spring and summer draught. Depending on the duration of crop vegetative period the total receipt of photosynthetically active radiation (PhAR) annually made up from 90.9 to 93.1 kJ/cm².

The process of formation and accumulation of oil in crambe seeds starts from the moment of their formation and up until the ripening and depends on the external factors. On the initial stages of seeds development when they are still white and transparent the fat content made up 8.3 % . When the seeds reach green pureness when they are still eatery, the fat content in seeds increases almost by 3 times. In green firm seeds the rate of accumulation slightly decreases and the percent of its content increases only by 1.2 times. When the seeds reach milky0wax ripeness the accumulation rate sharply decreases but the maximum content of the oil (44.2%) is noted in seeds that reached wax ripeness.

The result of interaction of all quantitative criterion of the plant with the external conditions is manifested through the crop productivity. Crambe abyssinica yield changed depending on hydrothermic conditions and fluctuated in average from 2.29 to 2.72 t/ha. (table 3).

Table 3: Productivity of crambe abyssinica (2015-2017)

Years	Yield, t/ha	Oil content, %	Oil content, t/ha
2015	2.69	42.9	1.03
2016	2.72	42.6	1.03
2017	2.29	43.8	0.89
Average	2.57	43.1	0.98
$HCP_{0.5}$	0.27	0.89	0.28
Experimental precision, %	1.98	1.12	1.15
V, %	36.8	14.5	7.3

Stable high yield of seeds formed in 2016 (2.72 t/ha) at most favorable combination of temperature and water regime (HTC -1.1) and not significantly exceeded the productivity in 2015 (at HTC – 0.9) only by 0.03 t/ha. The lowest yield of crop was noted in arid 2017, 2.29 t/ha. Meanwhile, the content of fat in seeds was the highest – 43.8%. In average, for 3 years the oil content of crambe made up 42.6 – 43.8%.

Gross oil harvest annually didn't differ significantly and made up in average 0.98 t/ha, as this indicator is defined both by seeds harvest and fat content.

Crambe yield formation is greatly influenced by main element of harvest structure elements which has interacting in agrocoenosis. At variance analysis of correlation between harvest structure elements and crambe yield it was stated that the greatest contribution to yield forming is made by the number of pods on the plant. Its influence percent is 38.9%. Influence percent of individual plant productivity and mass of 1000 seeds made up 34.3 and 26.8 % correspondingly. Such distribution of influence percent of structure elements on the ultimate yield is changed depending on genotype and environment and shows the ability of crambe to form a stable yield from year to year.

Quality analysis of crambe oil shows that the biggest share in fatty-acid content falls on erucic acid, its content reaches 58.9%. The second best id oleic acid, its content in seeds reaches 15.2%. Linoleic and linolenic acids content reduces to 8.9 and 7.1 % correspondingly.

Sum content of saturated fatty acids, including palmitic, myristic and stearic acids makes up only 6.1%. Such proportion of fatty acids allows to use crambe oil mostly for technical purposes.

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CONCLUSIONS

Short vegetation period of crambe (93-107 days) is one of the basic biological criterion of plants in forming stable agrocoenosis which is decisively important for acquiring stable harvest (up to 2.57 t/ha) and allowing to cultivate this crop in wide agroclimatic conditions.

High yield of crambe seeds, high oil content and optimal proportion of fatty acids in its content allow to classify crambe abyssinica as a promising crop of multi-purpose use..

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