



Asian Journal of Plant Sciences

ISSN 1682-3974

science
alert

ANSI*net*
an open access publisher
<http://ansinet.com>



Research Article

Cultivation of Minor Leguminous Crops in the Middle Cis-Ural Region

¹Razit Nurlygayanov, ¹Damir Islamgulov, ¹Ilgiz Asylbaev, ²Bulat Akhiyarov, ¹Fanzilya Giniyatova, ¹Aygiz Zainagabdinov, ¹Kamil Ismagilov and ¹Robert Davletshin

¹Department of Soil Science, Agrochemistry and Precision Farming,
Federal State Budgetary Educational Establishment of Higher Education Bashkir State Agrarian University, Ufa, Russian Federation

²Department of Crop Production, Plant Breeding and Biotechnology,
Federal State Budgetary Educational Establishment of Higher Education Bashkir State Agrarian University, Ufa, Russian Federation

Abstract

Background and Objective: Leguminous crops on arable land are sources of protein production. The purpose of the research is to develop elements of technology for the cultivation of minor leguminous crops (soy, vetch, chickpeas, broad beans) in the middle Cis-Ural Region to increase the yield and quality of main products. **Materials and Methods:** The research concept consisted of the formulation of a hypothesis based on the study of scientific literature, the latest achievements of production, the use of empirical methods-field and laboratory experiments, observation, measurement, comparison, theoretical methods-analysis and synthesis, generalization, mathematical research methods-variance and correlation analysis. **Results:** As a result of the decomposition of organic matter, a part of the nitrogen turns into a mineral form and increases soil fertility. The relevance of the research lies in the study of minor leguminous crops on arable land in the Republic of Bashkortostan, the importance of which lies in the production of vegetable protein and increasing soil fertility. **Conclusion:** The research methods consist of conducting field experiments aimed at increasing the productivity of leguminous crops of individual elements of the cultivation technology.

Key words: Acreage, broad beans, chickpeas, peas, soybeans, vetch, yield

Citation: Nurlygayanov, R., D. Islamgulov, I. Asylbaev, B. Akhiyarov and F. Giniyatova *et al.*, 2022. Cultivation of minor leguminous crops in the middle Cis-Ural Region. Asian J. Plant Sci., 21: 484-491.

Corresponding Author: Razit Nurlygayanov, Department of Soil Science, Agrochemistry and Precision Farming,
Federal State Budgetary Educational Establishment of Higher Education Bashkir State Agrarian University, Ufa, Russian Federation

Copyright: © 2022 Razit Nurlygayanov *et al.* This is an open access article distributed under the terms of the creative commons attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

According to their biological characteristics, leguminous crops have a wide area of cultivation in all agricultural regions of the planet, particularly in the Russian Federation, by changing species according to the purpose of destination and growing conditions¹.

Currently, 88% of species from the legume family have been studied, which differ in the unusual structure of flowers, pod fruits and the ability to form nodules²⁻⁴. In solving the problem of vegetable protein, a very important, if not decisive, role belongs to legumes, which have more protein in grain and by-products (straw) compared with cereals⁵⁻⁹.

Modern varieties of leguminous crops are characterized by a high nitrogen-fixing ability, due to plant residues, they are sources of nitrogen accumulation in the soil. The role of leguminous crops in the production of organic crop production is great¹⁰⁻¹². The most common of the grain legumes are peas (*Pisum sativum* L.), it is cultivated in almost all agricultural regions of the country. Peas are successfully cultivated in many countries of the world, including the Russian Federation¹³⁻¹⁸.

After peas, the leading leguminous crop is vetch. Vetch is cultivated for food in many parts of the world¹⁹. In the farms of the Republic of Bashkortostan, spring (*Vicia sativa* L.) and winter forms (*Vicia villosa* Roth.) are cultivated. Winter vetch mixed with winter cereals is cultivated for green fodder, grain seedling and grain fodder. In 2020, the areas of vetch in the Republic of Bashkortostan were given to 40.5 thousand hectares with a grain yield of 19.2 t ha⁻¹²⁰.

Chickpeas are a valuable legume crop in the arid zone^{21,22}. In recent years, chickpeas have been cultivated in the farms of the Republic of Bashkortostan. This crop is in great demand, both in foreign and domestic markets²³.

The progressive development of animal husbandry in large agricultural holdings (the group of companies "Neral", "Eco-Niva", etc.), industrial poultry farming increase the demand for soybean grain. In world agriculture, soy is considered the main oilseed crop²⁴⁻²⁶. In the Republic of Bashkortostan, sunflower, rapeseed and flax are cultivated as the leading oilseed crops and soy is a source of protein for animal and poultry feed²⁷. The production of soybeans in the farms of the republic is spreading at a low rate, although the volume of crop production in the whole country is expanding.

Feed beans are widely used in world feed production²⁸. Feed beans mixed with corn for silage can increase the feed nutrition of the green mass, optimize the C: N ratio in feed²⁹.

Broad beans are widely used in world feed production^{28,29}. We consider the cultivation of multiple crops of silage crops with broad beans to be promising in the production of high-quality animal feed.

Thus, shortly, the areas of minor leguminous crops in the Cis-Ural Region should be increased for the production of high-protein grain and feed for food and feed purposes. This study is aimed to develop elements of technology for the cultivation of minor leguminous crops (soy, vetch, chickpeas, broad beans) in the middle Cis-Ural Region to increase the yield and quality of main products.

MATERIALS AND METHODS

Study area: Field experiments were made on the experimental field of the Department of Soil Science, Agrochemistry and Precision Agriculture of the Educational and Scientific Centre of the Bashkir State Agrarian University (BSAU) in the Southern forest-steppe zone, as well as in the Trans-Ural steppe zone of the Republic of Bashkortostan in 2018-2020.

Conditions and methods of research: The research concept is based on the analysis of scientific publications, assessment of natural-climatic and soil conditions, setting up a field experiment, conducting observations and laboratory analysis, statistical processing of the experimental data obtained and their analysis. The study uses generally accepted methods and state standards.

Field experiments, laboratory analysis of seed quality and statistical analysis of experimental data were carried out to solve these tasks.

Agrometeorological conditions in the years of research (2018-2020) were atypical but in general, they reflect the continental character of the climate of the middle Ural area, the vegetation period 2020 characterized by more arid conditions (STC = 0.8).

The object of the research was winter vetch, winter rye, broad beans, maize in mixed crops, soybeans and chickpeas in single agrocenoses.

To solve the tasks, field experience, laboratory analysis of the quality of grain and green mass and statistical processing of experimental data were made.

Field experience 1: The influence of harvest methods and times on the yield and quality of winter vetch grain in multiple crops³⁰. Scheme of field experience:

- Direct harvesting of the mixture at the humidity of the grain of the reference culture 14%
- Selection of rolls mown at the humidity of the grain of the reference culture 30%
- Selection of rolls mown at the humidity of the grain of the reference culture of 20%

Field experience 2: Yield and quality of green mass of multiple corn crops with broad beans. Scheme of field experience:

- Pure sowing of corn
- Pure sowing of broad beans
- Multiple crops of corn+broad beans

Broad beans of the Siberian variety were studied. The variety is included in the register approved in 2007 for all regions. The originators of the variety are the Federal Altai Scientific Centre of Agrobiotechnologies and the Siberian Federal Scientific Centre of Agrobiotechnologies of the Russian Academy of Sciences. Hybrid corn Krasnodarsky 194 MV. was included in the State Register in 2000 for many regions of the Russian Federation, including 9 (Ural). Seed production of the hybrid is carried out in the Krasnodar Territory in the APC KKP "Kuban" on a sterile basis of the "M" type CMS according to the scheme of complete restoration.

Field experience 3: The influence of the row spacing width on the height of the lower soybean. Scheme of field experience:

- Width of the row spacing is 15 cm
- Width of the row spacing is 30 cm
- Width of the row spacing is 45 cm
- Width of the row spacing is 70 cm

Field experience 4: The effect of Rizotorfin B on the yield of chickpea grain. Scheme of field experience:

- Seeds without processing
- Seeds with rhizotorphin B treatment

Field experiments were conducted in the Southern forest-steppe, pre-Ural and trans-Ural steppe zones of the Republic of Bashkortostan. The technology of cultivation of minor legumes (soybeans, vetch, chickpeas and broad beans) is generally accepted for the zone³¹.

RESULTS

Legumes for food. In the conditions of the pre-Ural steppe zone of the Republic of Bashkortostan, the harvest methods and times of winter crops increase the grain yield, particularly, winter vetch.

Winter vetch plants continue to vegetate, despite the maturation of the lower beans. During direct combining of the

mixture in the phase of full ripeness of the grain of the reference crop of winter rye with a humidity of 14%, the share of winter vetch in the total mass was 35% to a grain yield of 0.92 t ha⁻¹. The proportion of rye in the mixture was 65% to a grain yield of 1.70 t ha⁻¹.

When mowing the mixture into rolls at a grain moisture content of the reference crop of 30%, the yield of the grain mixture was 2.86 t ha⁻¹, which is 0.24 t ha⁻¹ higher than on the control. The increase in grain yield is due to an increase in the yield of the share of winter vetch in the grain mixture. Mowing of winter vetch plants stops the supply of mineral nutrition elements to plants from the root system, the outflow of nutrients from the lower parts to the seeds begins, which provides an increase in crop yield by 0.28 t ha⁻¹, grain mixtures -0.24 t ha⁻¹ in this variant, the winter vetch grain yield increased by 0.28 t ha⁻¹.

Selection of rolls, mown at a moisture content of the grain of the winter rye reference crop of 20%, provided a yield of the mixture of 3.13 and 0.51 t ha⁻¹ higher than in the control version. In this variant, the share of winter vetch was 43.0%, which is 8.0% higher. The yield of winter vetch grain was 1.53 t ha⁻¹. The decrease in the winter rye grain yield occurred due to a decrease in the flow of nutrients into the grain after mowing than in comparison with the presence of plants on the root (Table 1).

The protein yield increases due to an increase in the proportion of winter vetch in the grain mixture. Also, the protein content increases in winter rye grain-from 11.5-12.6. With separate harvesting on the rolls, there is a more intensive outflow of nutrients to the generative organ (grain). This phenomenon is more shown in winter vetch. Simultaneously with the increase in yield, or, definitely, with the completion of the water intake and mineral elements from the root system, all nutrients accumulate in the grain. Therefore, the protein content increases by 2% compared with the control option (root harvest). The average protein content in the grain mixture according to the variants of the field experiment increased from 14.5-16.3% (Table 2).

Modern technologies, technical equipment of farms and new crop varieties with a lower content of harmful substances in grain make it possible to grow broad beans for grain and green feed. A promising technique is the feed preparation based on multiple crops of broad beans with corn as green feed and a raw material conveyor for laying silage (monofeed).

In our studies, the yield of pure corn crops of the Krasnodar 194 SV hybrid was 36.0 t ha⁻¹, broad beans of the Siberian variety -21.0 t ha⁻¹, mixtures of corn and broad beans -32.0 t ha⁻¹. The protein content in the dry matter of broad

Table 1: Yield of winter crops in binary sowing at different harvest times and methods (in average, 2018-2020)

Harvest times and methods	Mixture (t ha ⁻¹)	Share of winter rye		Share of winter vetch	
		Percentage	t ha ⁻¹	Percentage	t ha ⁻¹
Single-phase harvesting at the grain moisture content of the reference crop 14%	2.62	65.0	1.70	35.0	0.92
Mowing of rolls at a grain moisture content of the reference culture of 30%	2.86	58.9	1.66	41.1	1.20
Mowing of rolls at the grain moisture content of the reference crop 20%	3.13	57.0	1.60	43.0	1.53
HCP ₀₅	0.16	-	0.11	-	0.09

Table 2: Protein content and yield in binary sowings of winter rye with winter vetch (2018-2020)

Harvest times and methods	Mixture		Winter rye		Winter vetch	
	Percentage	t ha ⁻¹	Percentage	t ha ⁻¹	Percentage	t ha ⁻¹
Single-phase harvesting at the grain moisture content of the reference crop 14%	14.5	0.3804	11.5	0.1955	20.1	0.1849
Mowing of rolls at a grain moisture content of the reference culture of 30%	16.1	0.4589	12.1	0.2009	21.5	0.2580
Mowing of rolls at the grain moisture content of the reference crop 20%	16.3	0.5397	12.6	0.2016	22.1	0.3381

Table 3: Yield and protein content of green mass of fodder crops (2020)

Crops	Yield of green mass (t ha ⁻¹)	Protein content (%)	Protein yield (t ha ⁻¹)
Corn, Krasnodarsky 194 SV	36.0	8.5	3.08
Broad beans, Siberian	21.0	13.0	2.92
Corn and broad beans (37.5+62.5)	32.0	10.9	3.49



Fig. 1: Losses of soybean grain at a low height of the lower bean

beans was 13.0%. The protein content in the dry matter of corn was 8.5%. The dry matter content of the mixture of corn and broad beans was 10.9%. The protein yield per hectare was: For corn -3.08 t ha⁻¹, for broad beans-29.2 t ha⁻¹, multiple crops of corn with broad beans-3.49 t ha⁻¹ (Table 3).

Soybean harvest losses depend on weather conditions, crop varieties, harvest methods, the equipment used, other unplanned human factors are also possible. Usually, in production conditions, due to the low height of the lower bean, losses are allowed due to a shortage of the combined cutting machine (Fig. 1).

In production conditions, commodity producers sow soybeans for seeds in various ways-ordinary and wide-row. The advantages of ordinary sowing are more optimal placement of seeds per unit area of nutrition. Plants are more favourably distributed in agrocenosis. At the same time, there are several disadvantages: With heavily clogged crops, it is necessary to carry out the herbicidal treatment. Plants develop without intraspecific competition, they branch freely, the lower bean is located closer to the soil surface. On average, in our studies, the height of the lower bean of the SibNIK-315 variety was 5-6 cm. This height with a surface slope of 1-3 is not completely captured by the cutting rotation of the combine and yield losses are allowed in the form of a shortage of the formed crop.

With an increase in the width of the row spacing by 30 cm, the intraspecific competition of soybean plants begins-the struggle for light. As a result, the distance of the plant internodes begins to lengthen and accordingly, the height of the lower bean rises, since the soybean flower is laid in the internodes of plants. In our studies, with a row spacing width of 30 cm, the height of the lower bean rose to 7-9 cm. At this height, the shortage of soybean seed yield is reduced but the use of row-to-row tillage is excluded.

With a row spacing width of 45 cm, the intraspecific competition of plants increases, which eventually raises the lower bean to a height of 10-12 cm. However, at this height, grain losses due to a shortage of the lower bean are not completely excluded.

The highest height of the lower bean of soybean plants was provided when sowing with a row spacing width of

70 cm. At this width, the greatest intraspecific competition of soybean plants was noted, which was affected by the tendency of plants to height. At this width, the conditions for double row-to-row tillage are created, which not only destroy weeds in the agrocenosis but also improve the water-air regimes of the soil, which activate the activity of the symbiotic apparatus of nodule bacteria. With this row spacing width, the height of the lower bean is at the level of 15-17 cm, which fully ensures the cut and losses in the form of a shortage of the lower bean are not allowed (Table 4).

In the Republic of Bashkortostan, the most favourable zones for chickpea cultivation are the Pre-Ural steppe, the Trans-Ural steppe, part of the Southern forest steppe.

Chickpeas are relatively undemanding to their previous crops. The main condition for its placement is the absence of perennial weeds on the field. The best previous crops for chickpeas are winter rye and wheat, spring cereals. When cultivating chickpeas in new growth areas, it is necessary to infect the soil nodule stamps of bacteria additionally by pretreating the seed material to obtain the greatest plant productivity due to symbiotic nitrogen.

During the chickpea research period, the onset of phenological phases of chickpea plant development and the duration of interphase periods were observed.

The interphase periods depend on abiotic factors and weather conditions of the crop season. Chickpea sowing in 2020 was carried out on May 20. Favourable conditions ensured the appearance of full shoots in 9-11 days after sowing, depending on the options. The weather conditions of the crop season ensured the timely germination and passage of the phases of plant development.

Shoots with inoculation lasted for 2 days without inoculation for 9 days (May 29), with inoculation for 11 days (June 1).

The period from germination to the beginning of flowering was 22-24 days, depending on the experience options. After 20-22 days after flowering, the phase of green ripeness came.

During the onset of wax ripeness, an increased air temperature was established, so this period (from the beginning of green ripeness to wax) lasted at the same level-for 10 days. The period of "wax ripeness-full ripeness" lasted for 10-11 days. Harvesting was carried out by direct combining (single-phase) in the variant with rhizotorphin B treatment, the ripening period was extended by 1 day.

In general, as the observations of our studies have shown, the treatment of the seed material with rhizotorphin B turned out to be more effective. The length of the growing season (from sowing to full ripeness of seeds) in the control variant was 81 days and on the treated seed plot with rhizotorphin B-93 days.

The late sowing of chickpeas on the farm is because the plants are heavily clogged with early spring weeds when sowing at an early date. Chickpeas also differ from peas in that seedlings appear when heat is established in the soil. When the soil is cold, the seeds are at rest and they are damaged by soil pests and diseases, the seeds do not give shoots or weak seedlings. When sowing chickpeas at the beginning of the third decade of May, it becomes possible to carry out pre-sowing destruction of seedlings of early spring weeds, which makes it possible to exclude herbicidal treatment of crops (Table 5).

Table 4: Dependence of the lower bean height from the row space (2019-2020)

Row space (cm)	Lower bean height (cm)
15	5-6
30	7-9
45	10-11
70	15-17

Table 5: Effect of seed treatment with rhizotorphin B on the interphase period of chickpea plants (sole proprietor of the farm "Pogorelov Yu. V.", 2020)

Phases	Without inoculation	With inoculation	Difference in growth and development
Sowing	20.05	20.05	0
Shoots	29.05	01.06	2 days
Beginning of flowering	30.06	06.06	6 days
Beginning of green ripeness	20.07	28.07	8 days
Waxy ripeness	31.07	10.08	10 days
Full ripeness	10.08	21.08	11 days
Length of the crop season	82	93	11 days

Table 6: Effect of rhizotorphin B on the structure of soybean seed yield (t ha⁻¹)

Methods	Number of plants (pcs./m ²)	Number of beans (per 1 m ²)	Number of seeds in one bean	Weight of 1000 seeds (g)	Yield (t ha ⁻¹)
Control (without processing)	17.5	15.3	1.2	264	0.85
Seed treatment with rhizotorphin B	18.0	16.3	1.4	273	1.12

To identify the effectiveness of rhizotorphin B action on the growth and development of chickpea plants, it is necessary to analyze the elements of the yield structure.

The structure of grain yield makes it possible to establish the regularities of the formation of plant productivity. The constituent elements of the grain yield structure are the number of cultivated plants for harvesting, the number of beans per 1 plant, the number of seeds in a bean and the weight of 1000 seeds.

In our studies, the yield of chickpea seeds in the control variant was 0.85 t ha^{-1} . At the harvest time, the number of productive plants was 17.5 pcs./m^2 . On average, 15.3 pcs. of beans were formed on one plant. In one bean, the number of seeds was 1.2 pcs. The mass of 1000 seeds was equal to 264 g. Seed treatment with the bio-product rhizotorphin B increased the productivity of chickpea crops. The number of plants per 1 m^2 increased by 0.5 pcs. , beans in one plant -1.0 pcs. , the number of seeds in one bean by 0.2 pcs. The weight of 1000 increased by 0.9 g. As a result, in the experimental version, the seed yield increased by 0.27 t ha^{-1} (Table 6).

DISCUSSION

In our research, the highest yield of grain mixture (3.13 t ha^{-1}) and protein yield (0.5397 t ha^{-1}) was obtained when mowing rolls with a grain moisture content of 20% of the reference crop. Thus, in the conditions of Western Siberia, to obtain high-quality winter vetch grain in binary crops with winter rye, it is recommended to carry out harvesting in two phases by selecting rolls at 14% moisture content of rye grain³². Our research results are consistent with these data, the only difference is in the conditions of Western Siberia, the growing season is relatively short compared to the Middle Urals. Scientists of the Federal State Budget Scientific Institution "Federal Williams Research Centre of Forage Production and Agroecology" recommend selecting a grain mixture at a moisture content of 16-18% of seeds in rolls³³. It is impossible to agree with this. At this moisture content of the grain mixture in winter vetch seeds, this indicator remains high.

Mixed crops of corn with fodder beans provided the highest protein yield per unit area -3.49 t ha^{-1} in comparison with single-species crops. The inclusion of high-protein legumes in the components increases the protein content³⁴, which was confirmed by our research.

The feeding area in rows narrows with wide-row sowing of soybeans by 70 cm. The plants begin to struggle for light, thereby increasing the length of the internodes and the height of attachment of the lower bean by 11-12 cm higher

compared with the sowing of row spacing of 15 cm, which is consistent with previously obtained data³⁵. The lower bean is also characterized by high grain quality the loss is also undesirable. Due to the shortage of the lower bean, losses can reach up to 8%³⁶.

As a result of the action of biological agents, the indicators of the elements of the chickpea yield structure increase: The number of seeds in a bean (1.0 pcs. and the mass of 1000 seeds ($+0.08 \text{ g}$), which are consistent with previously obtained data³⁷.

The studied methods of increasing the productivity of minor leguminous crops have shown their effectiveness and consistency with similar studies conducted in different parts of the country and of the world, enriched the theoretical and practical significance for the conditions of the middle Cis-Ural Region.

CONCLUSION

Studies have confirmed the hypothesis of the importance of improving individual elements of the cultivation technology of the studied leguminous crops. Separate harvesting of a mixture of winter vetch with winter rye at a grain moisture content of the winter rye reference crop of 20% increases the grain yield of the mixture by 0.51 t ha^{-1} , the protein content by 1.8% compared to direct combining. Sowing soybeans with a row spacing width of 70 cm provides the highest grain yield with the least losses during harvesting due to the lengthening of the height of the lower bean. Processing of chickpea seeds with the biological preparation rhizotorphin B increases grain yield by 0.27 t ha^{-1} with a production profitability of 151.6%.

SIGNIFICANCE STATEMENT

This study discovers the new technology for the cultivation of minor leguminous crops (soy, vetch, chickpeas, broad beans) that can be beneficial for increasing the yield and quality of main products. This study will help the researcher to uncover the critical areas of improving individual elements of the cultivation technology of the studied leguminous crops, to increase soil fertility due to the accumulation of biological nitrogen by assimilating molecular nitrogen from soil nitrogen and involving it in the biological cycle that many researchers were not able to explore. Thus a new theory on to produce more vegetable protein per area unit of arable land.

REFERENCES

1. Zotikov, V.I., V.S. Sidorenko and N.V. Gryadunova, 2018. Development of production of leguminous crops in the Russian federation. *Legumes Groat Crops*, 2: 4-10.
2. Blondelle, M.W.N., M. Clautilde, M.M.M. Solange, M. Chantal and M.P. Marie, 2019. Morphological characterization of four leguminous crops cultivated in two agro ecological zone: Western and Guinean Savannah highlands of cameroon. *Eur. Sci. J.*, 15: 389-407.
3. Graham, P.H. and C.P. Vance, 2003. Legumes: Importance and constraints to greater use. *Plant Physiol.*, 131: 872-877.
4. Macák, M., E. Candráková, I. Ďalović, P.V.V. Prasad and M. Farooq *et al.*, 2020. The influence of different fertilization strategies on the grain yield of field peas (*Pisum sativum* L.) under conventional and conservation tillage. *Agronomy*, Vol. 10. 10.3390/agronomy10111728.
5. Uzun, V., N. Shagaida and Z. Lerman, 2019. Russian agriculture: Growth and institutional challenges. *Land Use Policy*, 83: 475-487.
6. Ruggeri, R., R. Primi, P.P. Danieli, B. Ronchi and F. Rossini, 2017. Effects of seeding date and seeding rate on yield, proximate composition and total tannins content of two Kabuli chickpea cultivars. *Ital. J. Agron.*, 12: 201-207.
7. Sinha, R., V. Irulappan, B.S. Patil, P.C.O. Reddy and V. Ramegowda *et al.*, 2021. Low soil moisture predisposes field-grown chickpea plants to dry root rot disease: Evidence from simulation modeling and correlation analysis. *Sci. Rep.*, Vol. 11. 10.1038/s41598-021-85928-6.
8. Sheteiwy, M.S., D.F.I. Ali, Y.C. Xiong, M. Brestic and M. Skalicky *et al.*, 2021. Physiological and biochemical responses of soybean plants inoculated with arbuscular mycorrhizal fungi and *Bradyrhizobium* under drought stress. *BMC Plant Biol.*, Vol. 12. 10.1186/s12870-021-02949-z.
9. Buezo, J., Á. Sanz-Saez, J.F. Moran, D. Soba, I. Aranjuelo and R. Esteban, 2019. Drought tolerance response of high-yielding soybean varieties to mild drought: Physiological and photochemical adjustments. *Physiol. Plant.*, 166: 88-104.
10. Pinaeva, M.I., L.A. Mikhailova and Y.A. Akmanaeva, 2017. Impact of predecessor and mineral fertilizer doses on winter rye yield cultivated on turf-podzolic soil. *Perm Agrar. J.*, 19: 101-106.
11. Abrosimova, M., A. Makushev, O. Litvinova, N. Nesterova, L. Gordeeva, A. Semenova, M. Tolstova, 2020. Green Economy: Preconditions and Directions of Development in the Agricultural Sector. IOP Conference Series: Earth and Environmental Science, 1-2 June, 2019, IOP Publishing Ltd., Bristol, 1-7.
12. Weisany, W., Y. Raei and K.H. Allahverdipoor, 2013. Role of some of mineral nutrients in biological nitrogen fixation. *Bull. Environ. Pharmacol. Life Sci.*, 2: 77-84.
13. Olle, M. and S. Tamm, 2021. The effect of sowing rate and variety on the nutrient content of field peas. *Acta Agric. Scand. Sect. B-Soil Plant Sci.*, 71: 165-170.
14. Asik, B.B., A. Uzun and E. Acikgöz, 2020. Seeding rate and cultivar impacts on nutrient uptake of field pea under fertile soil condition. *Chil. J. Agric. Res.*, 80: 11-20.
15. Uzun, A., B.B. Asik and E. Acikgoz, 2017. Effects of different seeding rates on forage yield and quality components of pea cultivars under bursa conditions. *Turk. J. Field Crops*, 22: 126-133.
16. McCollough, M.R., E.R. Gallandt and T. Molloy, 2020. Band sowing with hoeing in organic grains: II. Evidence of improved weed management in spring wheat, oats, field peas and flax. *Weed Sci.*, 68: 294-300.
17. Semenova, E.V. and G.I. Proskuryakova, 2021. Results of the assessment of pea accessions (*Pisum sativum* L.) from VIR collection in Tambov region in 1995-2017. *Legumes Groat Crops*, 1: 5-13.
18. Pashtetskiy, V.S., L.A. Radchenko, E.N. Turin, K.G. Zhenchenko, 2021. The Productivity of Five-Field Crop Rotations and Their Influence on Humus Content in Southern Russia. The Open Access IOP Conference Series: Earth and Environmental Science (EES) Provides a Fast, Versatile and Cost-Effective Proceedings Publication Service, 4-5 July 2020, IOP Publishing Ltd., Bristol, 1-7.
19. Burns, G.A., T.J. Gilliland, D. Grogan, S. Watson and P. O'kiely, 2013. Assessment of herbage yield and quality traits of perennial ryegrasses from a national variety evaluation scheme. *J. Agric. Sci.*, 151: 331-346.
20. Semmana, U., T. Dinkalea and B. Ebab, 2019. Performance evaluation of improved vetch varieties/accessions at the highland of Guji Zone, Bore, Ethiopia. *Agri. Res. Tech.*, 20: 220-225.
21. Sinha, R., V. Irulappan, B. Mohan-Raju, A. Suganthi and M. Senthil-Kumar, 2019. Impact of drought stress on simultaneously occurring pathogen infection in field-grown chickpea. *Sci. Rep.*, Vol. 9. 10.1038/s41598-019-41463-z.
22. Srinivas, P., S.R. Babu, M. Sharma, P.N. Reddy and B. Pushpavathi, 2017. Effect of temperature on *Rhizoctonia bataticola* and dry root rot in chick pea. *Int. J. Curr. Microbiol. Appl. Sci.*, 6: 3349-3355.
23. Mthulisi, M. and M. Mcebisi, 2020. Current status of chickpea production: Opportunities for promoting, adoption and adapting the crop in Zimbabwe: A review. *J. Dryland Agric.*, 6: 1-9.
24. Falco, N., H.M. Wainwright, B. Dafflon, C. Ulrich and F. Soom *et al.*, 2021. Influence of soil heterogeneity on soybean plant development and crop yield evaluated using time-series of UAV and ground-based geophysical imagery. *Sci. Rep.*, Vol. 11. 10.1038/s41598-021-86480-z.

25. Yang, Q., G. Lin, H. Lv, C. Wang, Y. Yang and H. Liao, 2021. Environmental and genetic regulation of plant height in soybean. BMC Plant Biol., Vol. 21. 10.1186/s12870-021-02836-7.
26. Salvagiotti, F., L. Magnano, O. Ortez, J. Enrico and M. Barraco *et al*, 2021. Estimating nitrogen, phosphorus, potassium and sulfur uptake and requirement in soybean. Eur. J. Agron., Vol. 127. 10.1016/j.eja.2021.126289.
27. Nurlygaianov, R., R. Ismagilov, D. Islamgulov, B. Ahiyarov, R. Abdulvaleev, K. Ismagilov and F. Ginijtova, 2019. Agro-technical basis for spring rape seed productivity depending on different climatic zones of the Russian federation. Int. J. Adv. Sci. Technol., 27: 222-230.
28. Pasqualone, A., A. Abdallah and C. Summo, 2020. Symbolic meaning and use of broad beans in traditional foods of the Mediterranean Basin and the middle east. J. Ethnic Foods, Vol. 7. 10.1186/s42779-020-00073-1.
29. Ni, Q., V. Ranawana, H.E. Hayes, N.J. Hayward, D. Stead and V. Raikos, 2020. Addition of broad bean hull to wheat flour for the development of high-fiber bread: Effects on physical and nutritional properties. Foods, Vol. 9. 10.3390/foods9091192.
30. Khasanov, E., I. Gabitov, S. Mudarisov, R. Khamaletdinov and Z. Rakhimov *et al*, 2019. Justification of parameters of seed treater with an eccentrically fixed drum influencing the motion character and seed treatment modes. Bulg. J. Agric. Sci., 25: 119-128.
31. Khasanov, E., R. Khamaletdinov, S. Mudarisov, D. Shirokov and R. Akhunov, 2020. Optimization parameters of the spiral mixing chamber of the device for pre-sowing seed treatment with biological preparations. Comput. Electron. Agric., Vol. 173. 10.1016/j.compag.2020.105437.
32. Cernay, C., E. Pelzer and D. Makowski, 2016. A global experimental dataset for assessing grain legume production. Sci. Data, Vol. 3, 10.1038/sdata.2016.84.
33. Kosolapov, V., K. Ishmuratov, Y. Pobednov, V. Klimenko and V. Kosolapova *et al*, 2020. Multicomponent mixtures in the preparation of high-protein, energy-saturated silos. Res. J. Pharm. Biol. Chem. Sci., 11: 164-168.
34. Stulin, A.F., 2021. Cropping of Corn (*Zea mays* L.) in the Chernozem Zone of the European Part of Russia: Effects of Fertilization and Rotation on Yield and Soil Fertility. In: Exploring and Optimizing Agricultural Landscapes, Mueller, L., V.G. Sychev, N.M. Dronin and F. Eulenstein (Eds.), Springer Cham, International Publishing, New York, ISBN: 978-3-030-67448-9, pp: 585-604.
35. Nehbandani, A., A. Soltani, A. Hajjarpoor, A. Dadrasi and F. Nourbakhsh, 2020. Comprehensive yield gap analysis and optimizing agronomy practices of soybean in Iran. J. Agric. Sci., 158: 739-747.
36. Saniev, R.N., A.V. Vasin, N.V. Vasina, A.N. Prosandeev and E.S. Makarova, 2020. Soybean Production using Growth Stimulants. BIO Web of Conferences, 28 February, 2020, EDP Sciences, France, 1-6.
37. Ogola, J.B.O., 2015. Growth and yield response of chickpea to rhizobium inoculation: Productivity in relation to interception of radiation. Legume Res. An Int. J., 38: 837-843.