Adaptive technology of environmentally - friendly production of legumes in the dry steppe zones

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Abstract

Modern agronomic technologies must include environmentally- friendly technologies in crop growing. In Kazakhstan, despite its significant potential, environmentally-friendly farming is underdeveloped with little scientific backing. Therefore, the objectives of this study were to develop and suggest an adaptive technology for cultivation of legumes taking into account existing methodologies for environmentally-friendly production in the dry steppe zone of Akmola region, Northern Kazakhstan. In order to achieve the objectives, the study focused on determination of a complex impact of combination of agroecological conditions (incl. agro- climatic, content of selected heavy metals such as Cu and Zn in soil, weed pressure, etc.), contrasting soil cultivation technology (i.e. traditional vs zero- tillage), nutrient inputs (fertilizers, legume stimulators) and pesticides on growth and productivity of selected legume crops (peas and chickpeas). The overall agroecological and growing conditions were suitable for producing economically- important legume crops (i.e. pea and chickpea), despite the temperature fluctiations and soil moisture shortage. Despite the very low content of N and P in the upper soil layer, the Cu and Zn content was within the Maximum Permissible Limits (MPL) for Kazakhstan, with a low anticipated negative effect on target legume growth. The least number of weeds was recorded by the variant with application of biological preparation Respecta. The targeted legumes were better developed during the growing season under the traditional technology compared to zero- tillage technology, i.e. germination and seed viability, which might be attributed to better utilisation of soil air and improved soil porosity of the soil layer of 0- 20 cm when using traditional technology. Combinations of mineral fertilizer $CaSO_4 + 2H_2O_5$ with the innoculation promoter Rizotorfin, and Izagry Phosphorus with Rizotorfin may be recommended to farmers. The application of plant inoculation promoter Rizotorfin was more effective when combined with Phosphorus promoter Izagry Phosphorus. This combination i) reduced the time of passing the main phenophases of pea and chickpea, and the overall length of vegetation (in days). It gives farmers an opportunity to apply late sowing, e.g. in the beginning of June and use the higher temperatures during main vegetation period, and ii) had a positive impact on biological productivity of peas and chickpeas, i.e. an increase with percentage compared to control variant. The results have shown that seed inoculation with Rizotorfin (containg *Rhizobium* bacteria) and additional Phosphorus fertilizers would lead to significant increase of plant productivity, i.e. yield in the conditions of dry climate in Northern Kazakhstan.

Keywords: chickpea, *Cicer arietinum*, pea, *Pisum sativum* L., technology, traditional, zero - tillage

Introduction

Modern agriculture requires adaptive technologies to produce crops in environmentally-friendly way. In countries with developed agriculture, the emphasis today is on development of biological methods of cultivation of agricultural crops (Cook and Baker, 1996). For instance, more than 1 million ha of agricultural land, which is 6% of the total agricultural land of the country, were under organic farming in Germany in 2011 that is 3.4 times higher than 1995 (Losaf, 2006). Asia holds about 10% of the world's area of organic farmland with leaders such as China (2,3 million ha), India (5,280 million ha) and Indonesia (41,000 ha). Worldwide, organic production volume grows by about 10- 20% per year and the prices of organic food are higher than the prices of conventional food by not less than 30%. Organic agriculture is globally important as a method of “sustainable and environmentally friendly production” (Paull, 2015). However, the level of production to meet the growing needs is considered insufficient. According to Churkina et al. (2016), the need for increased crop productivity is related to the need for modern and environmentally-safe fertilizers as a source of various nutrients for plants.

In Kazakhstan, despite its significant potential, environmentally-friendly farming is underdeveloped with little scientific backing. According to foreign experts, most of certified producers are located in Southern Kazakhstan and only a small amount of organic durum wheat is produced in the northern region (FAO, 2013). Organic products are produced in Akmola, Aktobe, Almaty and Kostanay regions. Nevertheless, the land under organic certification is significant, i.e. at least 303 thousand ha 2014, such cereal production is over 161,000 tons, oilseed is more than 84,000 tons and legumes are more than 47,000 tons (Petrovna, 2015). But before utilizing the existing possibilities, sufficient range of adaptive technologies for various crops should be tested and proposed to farmers. Chemical fertilizers are a vital part of modern agriculture in Kazakhstan, where more than half of its arable lands have low humus content (2-4%) and nearly 18 million hectares of arable lands have very poor content of phosphorus (Mukhanbet et al., 2016).

Pea and chickpea are valuable and promising crops for Northern Kazakhstan, mainly because of volatile prices of grain on the international markets and the increasing demand for legumes. Their cultivation in the crop rotation can reduce proportion of nitrogen fertilisers for growing main crops by 15-20% without damaging their productivity. In addition, a good balance of nitrogen and carbon left by the legume residues promotes their mobilization in the process of decomposition and mineralization. Research by Serekpaev (1998) indicates that after harvesting, legumes leave in the soil an average of 200- 700 kg*ha^{-1} residues, which contain 45-130 kg N, 10- 20 kg P and 20- 70 kg K. Besides N- fixation, legumes saves significant amount of energy used to produce mineral fertilisers. They improve microbiological activity and soil structure which makes them suitable for organic production (Parincina, 1993). Agroecosystems are open systems that exhibit certain stability in functioning of biological cycles. One of the aims of agroecosystems is to obtain higher biomass (i.e. biological productivity) (Vlahova and Popov, 2014).

At present, the growing of annual legumes in Northern Kazakhstan is done by mainly using traditional technology. Most of the areas of cultivation are under adverse climate conditions, i.e. sharp continental climate of Northern Kazakhstan (Hickmann, 2006). The region is exposed to wind and water erosion and degradation of soil organic matter. According to recent research (Dvurechensky and Gilevich, 2011), the rejection of conventional tillage and replacing it with zero- tillage can be justified by the need to save soil moisture, to maintain soil fertility and to prevent soils from erosion processes. No- till (NT) is an agricultural practice or technology whereby a crop is established without any prior tillage. NT agriculture has received increasing interest worldwide from agricultural research and development workers, policymakers and mostly from farmers (Erenstein et al, 2008). However, based on experimental data from Northern Kazakhstan, Suleimenov (2005) notes that there cannot be a one- sided effect of the type of tillage for different soil and landscape conditions. Therefore, to reduce the intensity of tillage in dry steppe zone with soils of southern chernozems, there is a need to assess the impact of tillage on soil and on plants respectively.

Another aspect of assessing the agroecological conditions for legume growth is the presence of heavy metals (HM) in these soils and its relation to human (agriculture) activities. For instance, mineral and organic fertilizers and pesticides could be a potential source of pollution with zink (Zn), e.g. 36 years fertilization of 175 kg*ha^{-1} P per year (triple superphosphate) can increase Zn content in soil layer 0- 15 cm from 118 to 250 mg*kg^{-1} soil. Nitrogen fertilisers could also acidify soils and could make lead (Pb) and Zn more available for plants. In acidic soils, even normal Zn quantities may become toxic. The high HM concentrations might inhibit the plant growth and productivity (Chernenyuk, 2009). In the beginning of 90^{s}, the state control on environmental safety increased in Kazakhstan. A compulsory environmental assessment was introduced. But problems with ecologically-susceptible territories still remain unsolved (Suleimenov, 2005). According to data by the Ministry of Agriculture of Kazakhstan, in 2014 about 9,993.300 liters of pesticides were used and 84.3% of it in mainly 3 regions of Northern Kazakhstan, i.e. in Akmola- 3,023.400 liters, in Kostanaj- 2,155.800 liters and in Severo- Kazakhstanskoj- 3,156.000 liters. At present, production of cereals and other crops relies almost 100% on application of mineral fertilizers and chemical pesticides. Thus, a sustainable sector of agro-industrial complex for production of environmentally- friendly products has still emerging. One of the major constraints, also seen in Russia, is the lack of ready- to-use, integrated agroecological technologies that are adapted to local agroecological conditions.

The objectives of this study were to develop and suggest an adaptive technology for cultivation of legumes taking into account existing methodologies for environmentally-friendly production in the dry steppe zone of Akmola region, Northern Kazakhstan.

In order to achieve the objectives, the study focused on determination of a complex impact of combination of agroecological conditions (incl. agro- climatic, content of selected heavy metals such as Cu and Zn in soil, weed pressure, etc.), contrasting soil tillage (i.e. traditional and zero- tillage technology), nutrient inputs (fertilizers, legume stimulators) and pesticides on growth and productivity of selected legume crops (peas and chickpeas).

Materials and methods

Experimental studies were carried out in year 2014 and 2015, under open field conditions on the permanent experimental area of the Department of ‘Agriculture and crop production’ of Kazakh Agro- Technical University ‘S.Seifullin’ and in Agricultural complex ‘Novorybinskoe and Co’ Ltd. in Akkol district located in the central part of Akmola region. It borders on Bulandy region, on Shortandy in the south, on Astrakhan in the west and on Yereimentau region in the east. The laboratory analyses were executed in the Republican Scientific Research Guidance Center of Agrochemical Service in Kazakhstan.

Leguminous crops tested

The legume varieties for experiments, i.e. ‘Aksay leafless 55’ pea, with 90.0% economic value and ‘Jubilee’ chickpea with economic value of 92.0%, were approved for use in Akmola region. Sowing quality of seeds of the pea and chickpea were determined according to GOST (1984) ‘Seeds of crops’ in the laboratory of seed studies of KATU ‘S.Seifullin’.

The study used inoculation of legume seeds with N- fixing bacteria of the genus *Rhizobium* because it was anticipated that seed inoculation would lead to significant increase of plant productivity, i.e. yield (Serekpaev, 1998). Rizotorfin is a preparation of high - efficient legume bacteria grown in peat substrate enriched with carbohydrates, vitamins and minor- nutrient elements. The content in 1 cm^3 of preparation (titer) is not less than 2.5 billion bacteria. The application rate of Rizotorfin is 400 - 600 $g*ha^{-1}$ rate of seeds. The seeds were treated with the preparation Rizotorfin (registered for bacterial seed treatment) approximately 5 hours prior to sowing.

Agrotechnology

The plot selection for the field experiments was based on the study of soils and agrochemical maps, and a field history record book containing preceding crops, agricultural techniques, organic and mineral fertilisers and lime applied.

The area of a single experimental plot was 12 m^2, the area of the registration plot was 10 m^2. The total area of the experimental site is 1,000 m^2. The allocation of variants in the experiment is systematic with sequential replication.

The sowing was done in second decade of May 2014 and 2015 under field conditions, with a seeding rate of 0.8 million of germinating $seeds*ha^{-1}$ at the depth of 6 cm, where soil moisture is accumulated only on the basis of natural rainfall.

Respecting the principles of traditional technology for cultivation of legumes, chemicals and fertilizers have not been applied on the selected pilot area before sowing. A preceding crop was perennial grasses (wheat grass) of long-term (more than 25 years) use. The area where saving (zero- tillage) technology of cultivation was applied was selected having regards to preceding wheat stubble-retention fields. Mineral fertilizers and chemicals have not been previously applied on these plots. Registration and observation in the experiments were carried out in compliance with the methods of conducting experiments and State variety testing of crops in the laboratory of KATU ‘S.Seifullin’.

Traditional technology

In the autumn of the first year (2014), a plowing (furrow slice inversion) of perennial grasses was done on the plot with the plow (PLN 5-35) to the depth of 25 cm, followed by disking with the field drag (BDT-10) to the depth of 6 cm using traditional technology of cultivation of legumes. In the spring of 2015 with the onset of soil workability (2nd decade of April), a harrowing with ZBZTU-1 spike-tooth harrow that was hitch-mounted to C-11U to mulch moisture (leveling the soil surface) and to extirpate early spring weeds in "white thread" phase was conducted. Subsequently, a pre-sowing cultivation with simultaneous harrowing done with KPNA-3 mounted cultivators with ZBZS-1 average harrows hitched to SN-54A and rolling down with 3 KKSH-6A star-wheeled rollers and T-75 tractor was conducted prior to sowing (1st decade of May).

Zero-tillage technology

Farming techniques for soil cultivation were not used before sowing.

Fertilization

The treatment of plants with phosphorus stimulator (a liquid fertilizer Izagri phosphorus) was done in the phase of budding of pea and chickpea as a foliar treatment with knapsack sprayer 0.7 liter*ha^{-1} twice in July.

Izagry phosphorus is a growth stimulator in a water soluble suspension containing high phosphorous content (27.7%) and having physiologically-active properties. It has been proven to enhance root growth and to promote development of above-ground plant biomass. In plants, Izagry phosphorus increases metabolism, increases the activity of soil microorganisms, which in turn contributes to improving the mineral feeding of plants (Artykov, 2000). In small doses, it stimulates the growth and development of plants, and accelerates their maturation with 7-10 days. This is especially important in Northern Kazakhstan where there is a short vegetative season. Izagry phosphorus increases efficiency of applied mineral fertilisers, improves mineral feeding of plants especially in extreme conditions (high or low temperature, insufficient or excessive moisture), increases resistance plants to diseases, leads to increased plant growth (plant height), increases yield, accelerates seeds’ ripening and improves product quality.

Plant protection treatments

Application of chemical preparation Pivot- 10% at 0.5 liter*ha^{-1} was done with knapsack sprayer before seedling emergence on the 3rd and 4th day after seeding (in variant III and IV). Pivot is a selective herbicide, water- soluble concentrate for destruction of annual and perennial grasses, including quarantine weeds. Pivot can be applied once during vegetation, it is multipurposed and effective at low application rates, it is also low - volatile, so it has insignificant losses for different methods of application, and it is resistant to rainwash for an hour.

Spraying with biological preparation Respecta (Biona®) at 0.9 liter*ha^{-1} in the phase of budding by a knapsack sprayer in July, was meant to control diseases caused by pathogenic microorganisms (fungal and bacterial). It also acts as a stimulator of germination rate and vitality of the germinated seed, of root nodulation and P-utilization.

Statistical analysis of the received experimental data was performed by using Statistica (StatSoft, Inc., 2004) software. A factorial analysis of variance (ANOVA) was used to analyse the differences between treatments.

Treatments

The field experiments were made according to the following scheme:

Variant I- Traditional technology

Impact of Izagry Phosphorus, preparation Rizotorfin and under biological preparation Respecta, on the growth of pea and chickpea under traditional technology:

1. Control (single- crop sowing)
2. Respecta
3. Izagry Phosphorus
4. Izagry Phosphorus + Rizotorfin

Variant II- Zero-tillage technology

Impact of Izagry Phosphorus, preparation Rizotorfin and under biological preparation Respecta, on the growth of pea and chickpea under to zero - tillage technology:

1. Control (single- crop sowing)
2. Respecta
3. Izagry Phosphorus
4. Izagry Phosphorus + Rizotorfin

Variant III- Traditional technology

Impact of Phosphorus fertilizer ($CaSO_4$ + $2N_2O_5$), preparation Rizotorfin and under chemical preparation Pivot on the growth of pea and chickpea under traditional technology:

1. Control (single-crop sowing)

2. Pivot

3. Phosphorus fertilizer ($CaSO_4 + 2N_2O_5$)

4. Phosphorus fertilizer ($CaSO_4 + 2N_2O_5$) + Rizotorfin

Variant IV- Zero-tillage technology

Impact of Phosphorus fertilizer ($CaSO_4 + 2N_2O_5$), preparation Rizotorfin and under chemical preparation Pivot on the growth of pea and chickpea under zero - tillage technology:

1. Control (single- crop sowing)

2. Pivot

3. Phosphorus fertilizer ($CaSO_4 + 2N_2O_5$)

4. Phosphorus fertilizer ($CaSO_4 + 2N_2O_5$) + Rizotorfin

Study parameters

Meteorological parameters and agroclimatic characteristics

The climate of the region of the experiment is continental and dry. The average annual precipitation is 300- 350 mm as approximately 200- 250 mm of it come during the warm period that lasts from mid- April to mid- September. According to the long-time average annual data for 2014- 2015, the absolute maximum temperature is in June, July and August ranging from +16 °C to +22 °C. The lowest temperature is in December, January and February. The increase of mean daily temperature over 0 °C takes place in the first decade of April; the warm period lasts from 75 to 90 days. The frost- free period lasts 110- 120 days a year. Snow cover is resistant for up to 5 months as the average thickness of the cover reaches 20- 35 cm. Frosts begin in the second half of September. In some years, frosts occur at the end of August. Snow cover appears in the middle of October.

Phenological observations

They were carried out in accordance with the method approved by State Commission for Variety Testing Crops in Kazakhstan. Observations were made from sowing of legume seeds to ripening of legume plants on four permanent plots of 0.25 m^2 each by two non- adjacent replications. Beginning of the respective phenophase was considered when not less than 10% of the plants entered this phenophase and the total phase was marked when not less than 75% of the plants were inside this phenophase. Germination of seeds was determined by the formula:

$$П_в = \frac{Г \cdot 100}{Н_в} \qquad (1)$$

where $П_в$ is germination in %; Г is actual plant density on shoots in plants*m^{-2}; and $Н_в$ is seeding rate in seeds*m^{-2}.

Plant viability was determined by the formulae:

$$A = \frac{Bx100}{C} \qquad (2)$$

where A number of plants which produced seeds in the harvesting phase, %; B - number of plants in harvesting phase, pieces*m^{-2}; C- number of plants in the full shoots phase, pieces*m^{-2}. Plant density was defined twice: after emergence and at harvest by counting the plants in all variants. For this purpose, four plots of 0.25 m^2 each were randomly placed on two non- adjacent replicates. Number of seeds was determined by analysing the structure of the crop and the yield.

Heavy metals (HM) determination

The soils are southern black vertosols. Humus content in the upper layer is approximately 3% on average, the absorption capacity is 41 mg*eqv, CO_2- 1.8- 3.0 %. The soil effervescence comes from the surface. The presence of absorbed sodium proves weak alkalinity of the soils. The content of the absorbed sodium is about 2% in the 0- 10 cm layer. According to the surface topography the southern carbonate black soils lie in the undulating plain under the feather- fescue plant grouping with small admixture of steppe grasses in yellow brown quaternary carbonate heavy loam and light clay with deep- lying ground water. The humus horizon (A + B_1) is equal to an average of 40.5 cm and has dark gray color often with a slight brown tint, crumbly structure, B_2 horizon thickness is 65 cm. The visible border of gypsum horizon extends to the depth of 90-150 cm; the soil effervescence is at the bottom of B_1 horizon or at the border of the humus layer.

The study examines the dynamics of the most hazardous class of heavy metals in soil and plants, i.e. Copper (Cu) and Zink (Zn). Soil samples were taken twice a year, i.e. before sowing (in spring after snow melting, and before harvesting (in autumn few days prior to harvesting crops). Each variant was replicated 3 times in plots. Soil samples were taken with a drill from the top soil layer of 25 cm by intervals, i.e. 0-5, 5-10, 10-20 (25) cm. Samples were distributed in a thin layer on a polyethylene film, and then were mixed up thoroughly and using approved methodology and then placed in plastic bags containing minimum 1 kg of soil.

Determination of heavy metals in soil and plants was done using atom-absorption spectrometer with flame or non-flame atomization in accordance with GOST 8.010-72 (2015). Mobile forms of heavy metals (HM) were extracted by using extractors (i.e. 1 M HCl and acetic- ammonium buffer solution with pH of 4.8) adopted by agro- chemical service for extracting available microelements for plants for chernozem soils. Extraction was done in replications for each sample. With the entire filtrate available, the HM is determined using atom-absorption method in flame of acetilen- oxigen. The HM content in the analysed samples was calculated using the formulae:

$$X = \frac{V \times (A_1 - A_0)}{m} \qquad (3)$$

where: X- amount of the analysed metal element in air- dry soil sample- part per million (mg*kg^{-1}); A_1- concentration of the metal element in the analysed acidic (buffer) soil solution, (mg*dm^{-3}); A_0- concentration of the metal element in a control sample, ($mg*dm^{-3}$); V- volume of analysed solution, cm^3; m- weight of air-dry soil sample, g.

Two laboratory sample analysis were done in parallel and then mean of the two was calculated for one soil sample. Parameters of correctness of the calculations of HM amount in soil were calculated in accordance with national standards, i.e. GOST (2015). At present, there are national standards for Maximum Permissible Limits (MPL) for individual elements such as Cu, Zn, Ag, Pb, etc. in soil, and considering their toxicity (Bespamatnov and Corotkov, 1985).

Results and discussion

Soil conditions

The main soil fertility parameters of the experimental plot are shown in Table 1 below. According to the soil classification based on humus content (by Tyurin method, in %), on the content of labile phosphorus and nitrate nitrogen in the soil by Chernenok' gradation ($mg*kg^{-1}$), the soil can be classified as one with very low content of these elements in the layer of 0- 20 cm and 0- 40 cm. According to the rate of exchangeable potassium, determined by Machigin method ($mg*kg^{-1}$), the soil belongs to the groups with relatively high content of exchangable potassium. Assessing the degree of acidity, the soil ranges from neutral to average alkaline.

Table 1. Major soil parameters of experimental soils, mean of 2014 and 2015

Technology	Soil layer cm	Humus %	P_2O_5 $mg*kg^{-1}$	K_2O $mg*kg^{-1}$	$N\text{-}NO_3$ $mg*kg^{-1}$	pH
Traditional	0-20	2.89	3.61	521.3	3.11	7.22
	20-40		2.31		3.23	7.26
Zero- tillage	0-20	2.51	2.51	452.1	2.28	7.00
	20-40		2.60		2.44	7.12

Climate conditions

The snow cover height on the experimental plots by the end of February (as an average from 2014 and 2015) averaged 22.6 cm, the weight was 10.1 g, the density was 0.294 $g*cm^{-3}$, the amount of water was 36.4 mm. In the spring, moisture reserves in one meter of soil layer before sowing ranged on an average from 57.5 mm to 79.6 mm (under the two different technologies).

The reserve of available moisture for harvest in variants under traditional technology was 33.7 mm, and in variants under zero- tillage technology was 40.2 mm. The rainfall during the growing season was irregular except May, when the amount of precipitation was lower in comparison with the long- time average annual indicators. The amount of precipitation in the winter months (i.e. January, February) was lower than the long- time average annual rates by 1.5- 2.2 times. In March the precipitation was equal to the long- time average annual index. In the following spring months the amount of precipitation exceeded the long - time average annual index by 1.8 times. In the summer months, the rainfall in June was lower than the long-time average annual index by 19.3 mm, in July by 24.9 mm and in August by 2.3 mm.

The monitoring of the bioclimatic parameters of Agricultural complex in Akkol district located in the central part of Akmola region showed that for 2014- 2015, the average weather conditions were equal to the long- time average annual parameters. Thus, the selected varieties of legume crops can be successfully cultivated in this region. However, it should be noted that in spite of sufficient amount of accumulated active temperatures during the growing season (from sowing to full ripeness) in the conditions of the terrain, there are strong temperature fluctuations. The temperature rose up to +36.0 °C during the day and fell down to +20 °C at night, which had negative impact on the growth and development of target leguminous crops during the growing season. Assessing the moisture conditions, it should be noted that the negative impact of irregular precipitation during the growing season resulted in soil moisture shortage in the phase of maximum water consumption in the second half of the summer (mid- July and beginning of August), as the precipitation during this period was 20 mm lower comparied to the long- time average annual indicators. The calculations of hydrothermal index (HTI) made on the basis of the prevailing temperature and the amount of precipitation during the growing season (HTI -1.1) characterize the meteorological conditions of the year 2014- 2015 as slightly dry.

Content of heavy metals (HM) in soil and in target legumes

There is an intersting trend shown by heavy metals (HM) content under the two contrasting growing technologies. Under traditional technology, Cu and Zn content in soil after application of biological preparation- Respecta and chemical preparation- Pivot were higher than in the control variant (Table 2), but were still within the Maximum Permissible Limits (MPL) for Kazkhstan (KZ). They fall within the class 1 and 2 of hazard for heavy metals in the country (Table 3), meaning that they are not retained in the soil but might migrate into plants and might have a negative impact on the nutritional value of agricultural products.

In contrast, under zero - tillage technology, the Cu and Zn content in soil after application of biological preparation- Respecta and chemical preparation- Pivot were higher than in the control variant (Table 2), still within the Maximum Permissible Limits for Kazkhstan, but fall within the class 3 of hazard for heavy metals in the country (Table 3), meaning that they are retained in the soil, do not migrate into plants and might have an almost no negative impact on the nutritional value of agricultural products.

The Cu and Zn content in soil and plants, after application of chemical preparation Pivot, was higher than in variants treated with biological preparation Respecta, and almost twice as higher under zero - tillage than under traditional technology (Table 2) as also recommended by Kyrychenko (2015).

Table 2. Content of heavy metals (Cu and Zn) in soil and plants (mg*kg^{-1}) during growing season, mean of spring and autumn

Variants	Contents in soil		Contents in plants		MPL
	Cu	Zn	Cu	Zn	
Traditional technology					
Control (no treatment)	0.010	0.042	0.005	0.032	Within limit
Respecta	0.023	0.056	0.013	0.034	Within limit
Pivot	0.120	0.240	0.062	0.137	Within limit
Zero - tillage technology					
Control (clean crop)	0.017	0.062	0.009	0.020	Within limit
Respecta	0.038	0.081	0.021	0.042	Within limit
Pivot	0.370	0.520	0.170	0.230	Within limit

* In soil, national MPL for heavy metal content of Kazakhstan: Cu- 3.0 mg*кg^{-1}, Zn- 23.0 mg*кg^{-1}

MPL - Maximum Permissible Limits

Table 3. Class of hazard for heavy metals (Cu, Zn) (according to GOST standard)

Indices	Standards for class of hazard 1st	2nd	3rd
Toxicity LD_{50} *	to 200	from 200	to 1000
Persistence in the soil, in months	**	More than 12	From 6 - 12
MPL in the soil, mg*kg^{-1}	Less than 0.2	from 0.2-0.5	More than 0.5
Migration	Migrate	Migrate a little	Don’t migrate
Persistence in plants, in months **	3 and more	from 1 to 3	Less than 1
Impact on the nutritional value of agricultural products	Strong	Medium	No effect

* LD - Lethal Dose of the chemical that causes death of 50% of the animals, mg*kg^{-1} of body weight when introduced.

** Persistence in soil - the duration of maintaining biological activity of the pollutant chemical in soil, characterizing the degree of its resistance to the process of decomposition.

Weed pressure

The growing season showed the emergence of the weed species such as wild oat (*Avena fatua* L.), redroot pigweed (*Amaranthus retroflexus*), field sow thistle (*Sonchus arvensis* L.). Upon traditional technology and different variants (Table 4), annual weeds ranged from 4 to 10 plants*m^{-2} and perennial weeds up to 1 plant*m^{-2}.

Table 4. Weed density (number of plants*m^{-2}) in target legume fields upon contrasting tilage technologies, mean of two crops and mean of 2014- 2015

Variants	Branching phase		Blossoming phase		Ripening phase	
	Pieces *m^{-2}	g*m^{-2}	Pieces *m^{-2}	g*m^{-2}	Pieces *m^{-2}	g*m^{-2}
Traditional technology						
Control (no treatment)	11.0	3.3	18.0	10.7	21.0	30.7
Respecta	3.0	1.0	1.0	0.5	0.0	0.0
Pivot	6.0	1.6	3.0	3.5	1.0	0.5
Zero- tillage technology						
Control (no treatment)	16.0	4.2	20.0	18.2	25.0	33.4
Respecta	10.0	3.1	3.0	3.9	1.0	1.7
Pivot)	12.0	3.6	6.0	10.4	3.0	7.2

Under zero- tillage technology, annual weeds ranged from 10 to 16 plants*m^{-2}, perennial from 1 to 5 plants*m^{-2}. Under both traditional and zero - tillage technology, the least number of weeds was shown by the variant with application of biological preparation Respecta which confirms findings of Amini et al. (2015).

According to the weed density scale (Moiseychenko et al., 1996), the level of weed density is weak under traditional technology and average under the zero- tillage technology (Table 5). In addition to soil tillage, application of biological preparation Respecta can be recommended as i) it delivers the least weed density per unit of land, ii) leaves a low Cu and Zn content in soil and in plants, and iii) posses low risk to the environment and plant quality and safety without compromising the maintenance of a low weed population.

Table 5. Weed density (number of plants*m^{-2}) scale of the leguminous crops in relation to variants and contrasting tillage technologies

Variants	Pea		Chickpea		Points of weed growth	Level of weed density
	Annual	Perennial	Annual	Perennial		
Traditional technology						
Control (no treatment)	10-50	1-5	10-50	1-5	1	average
Respecta	<10	<1	<10	<1	1	weak
Pivot	<10	<1	<10	<1	1	weak
Zero - tillage technology						
Control (no treatment)	10-50	1-5	10-50	1-5	2	average
Respecta	10-50	1-5	10-50	1-5	2	average
Pivot	10-50	1-5	10-50	1-5	2	average

Field germination and Plant viability

The results from biometric parameters, measured during the field growing period, show that the field germination of pea crops grown under traditional technology ranged from 75.0% to 79.4%, and by zero- tillage technology from 66.0% to 74.6%, respectively (Table 6). The best field germination was observed after application of the combination of dual superphosphate ($CaSO_4 + 2H_2O_5$) with preparation Rizotorfin using the traditional technology, followed by the same combination under zero- tillage technology. The field germination rate of chickpea under traditional technology ranged from 70.0% to 78.4%, and by zero- tillage technology from 63.3% to 73.4%.

The viability of peas plants grown under traditional technology ranged from 70.0% to 76.6% and under zero- tillage technology from 61.0% to 75.2%. The best plant viability was shown by the variant with application of Izagry Phosphorus and preparation Rizotorfin. The viability of chickpea ranged from 71.3% to 85.6%, under traditional technology, and from 70.0% to 80.6% under zero- tillage technology.

Thus, the combination of mineral fertilizer $CaSO_4 + 2H_2O_5$ and the inoculation promoter Rizotorfin impacted positively the germination of peas and chickpeas (Table 6). Similarly, the application of Izagry Phosphorus and Rizotorfin had positive effect on the plant viability. Under traditional technology pea and chickpea showed better germination and viability. It might be attributed to better utilisation of soil air and improved soil porosity of the soil layer of 0- 20 cm when using traditional technology, so plant nutrients required for growth and development become readily available.

Table 6. Germination and viability of pea and chickpea after treatments (variants) and application of contrasting tillage technologies

Variants	Field germination rate, %		Plant viability, %	
	Pea	Chickpea	Pea	Chickpea
Traditional technology				
Control	75.0	70.0	70.0	71.3
Izagry Phosphorus	75.2	70.2	76.2	85.4
Izagry Phosphorus + Rizotorfin	77.5	73.0	76.6	85.6
$CaSO_4 + 2H_2O_5$	78.2	75.4	73.2	75.0
$CaSO_4 + 2H_2O_5$ + Rizotorfin	79.4	78.4	73.6	75.2
Zero- tillage technology				
Control	66.0	63.3	61.0	70.0
Izagry Phosphorus	66.9	65.0	75.0	80.0
Izagry Phosphorus + Rizotorfin	68.2	67.8	75.2	80.6
$CaSO_4 + 2H_2O_5$	72.3	70.0	63.0	75.1
$CaSO_4 + 2H_2O_5$ + Rizotorfin	74.6	73.4	63.4	75.4

The ANOVA results suggest that effect of interaction of major factors, i.e. agro- technology and treatment (variant) on germination and viability of pea and chickpea (in %) is significant ($P<0.05$). The germination and seed viability of both legumes under traditional technology is higher in all treatments compared to zero- tillage technology and combinations of mineral fertilizer $CaSO_4 + 2H_2O_5$ and the inoculation promoter Rizotorfin and Izagry Phosphorus and Rizotorfin may be recommended to farmers.

Plant height and lenght of the growing season

The average plant height in relation to main interphase periods of targeted legumes is shown on Table 7 and 8. During the growing season, pea plant height under the traditional technology and treatments ranged from 6.0 cm to 36.5 cm with the duration of the growing season from 90 to 96 days. As for the the zero- tillage technology, the pea plant height by the variants of the experiment ranged from 4.0 cm to 28.6 cm with the growing season length from 90 to 96 days.

The chickpea plant height under the traditional technology and treatments (variants) ranged from 4.0 cm to 34.7 cm with a growing season length from 101 to 105 days. As for the the zero- tillage technology, the chickpea plant height ranged from 3.6 cm to 31.5 cm with a growing season length from 100 to 105 days. In the beginning of growth of pea and chickpea (i.e. the phases of shoots- branching), treatment (variant) with dual superphosphate and Rizotorfin produced the tallest plants. Later (the phases of budding to ripening), the plant height was highest after treatment with the combination of Izagry Phosphorus and preparation Rizotorfin. This effect may be attributed to two factors, i) when mineral fertiliser dual superphosphate was applied before sowing, it had a positive effect during the plant germination, but at later growing stages this effect decreased because the root system went down to a depth of approximately 50 cm, while the fertiliser was active at the layer of 0- 20 cm, and ii) plant treatment with Izagry Phosphorus (done on the 25 of June) at later plant stages (i.e. the phase of budding). Thus, the leguminous crops were better developed during the growing season under the traditional technology than the zero- tillage technology. The biological preparations had a positive impact on legume growth. In comparison with the plants of control variant, plant height of the leguminous plants was higher by 0.6-10.4 cm.

The application of plant inoculation product Rizotorfin was effective only in combination with phosphorus promoter Izagry Phosphorus. The least significant difference was an error within 5%. Addition of the combination of Phosphorus- growth stimulator and preparation Rizotorfin reduced the time of passing the main phenophases of pea and chickpea, and the overall length of vegetation (in days) (i.e. vegetation period was significantly lower ($P<0.05$) compared to control variant). The result provides farmers with an opportunity to apply late sowing, e.g. in the beginning of June and use the higher temperatures during main vegetation period.

Table 7. Length of the interphase periods (in days) of pea and the height of plants (cm) during the growing season in relation to the treatments (variants) and the contrasting technologies, mean of 2014 and 2015

Variants	Phase of plant development												Length of growing period, days
	Shooting		Branching		Budding		Blossoming		Pod formation		Ripening		
	Date	Height, cm	Date	Height, cm	Date	Height, cm	Date	Height, cm	Date	Height, cm	Date	Height, cm	
Traditional technology													
Control	06.06	6.0	15.06	13.2	07.07	20.5	22.07	25.6	08.08	25.9	30.08	26.4	96
Izagry Phosphorus	06.06	6.5	15.06	13.5	07.07	24.8	21.07	34.1	04.08	34.5	27.08	36.3	90
Izagry Phosphorus + Rizotorfin	06.06	6.8	15.06	14.0	07.07	27.0	21.07	32.1	04.08	35.1	27.08	36.5	90
$CaSO_4 + 2H_2O_5$	06.06	7.2	15.06	15.3	07.07	25.0	21.07	28.2	04.08	28.5	27.08	30.2	96
$CaSO_4 + 2H_2O_5$+ Rizotorfin	06.06	7.6	15.06	15.9	07.07	25.4	21.07	28.6	04.08	29.1	27.08	31.1	96
Zero- tillage technology													
Control	06.06	4.0	15.06	10.6	07.07	18.7	22.07	19.8	08.08	20.1	30.08	20.8	96
Izagry Phosphorus	06.06	4.0	15.06	10.8	07.07	22.4	21.07	28.2	04.08	29.4	27.08	28.0	90
Izagry Phosphorus + Rizotorfin	06.06	5.0	15.06	12.0	07.07	26.5	21.07	29.1	04.08	30.3	27.08	28.6	90
$CaSO_4 + 2H_2O_5$	06.06	6.2	15.06	13.6	07.07	20.2	21.07	25.2	04.08	25.8	27.08	26.0	96
$CaSO_4 + 2H_2O_5$ +Rizotorfin	06.06	6.6	15.06	14.0	07.07	20.7	21.07	26.3	04.08	26.9	27.08	27.2	96

Table 8. Length of the interphase periods (in days) of chickpea and the height of plants (cm) during the growing season in relation to the treatments (variants) and the contrasting technologies, mean of 2014 and 2015

Variants	Phase of plant development												Length of the growing period, days
	Shooting		Branching		Budding		Blossoming		Pod formation		Ripening		
	Date	Height, cm	Date	Height, cm	Date	Height, cm	Date	Height, cm	Date	Height, cm	Date	Height, cm	
Traditional technology													
Control	10.06	4.0	23.06	12.2	13.07	17.0	23.07	24.0	10.08	25.0	08.09	26.8	105
Izagry Phosphorus	10.06	4.6	23.06	13.0	13.07	19.2	22.07	31.3	06.08	32.0	05.09	34.5	101
Izagry Phosphorus + Rizotorfin	10.06	4.7	23.06	13.7	13.07	23.5	22.07	32.0	06.08	32.6	05.09	34.7	101
$CaSO_4 + 2H_2O_5$	10.06	6.0	23.06	14.6	13.07	20.2	22.07	25.1	06.08	27.2	05.09	28.2	105
$CaSO_4 + 2H_2O_5$ + Rizotorfin	10.06	6.6	23.06	15.2	13.07	21.1	22.07	25.7	06.08	28.0	05.09	29.1	105
Zero- tillage technology													
Control	10.06	3.6	23.06	8.3	13.07	14.6	24.07	18.9	10.08	19.9	08.09	21.1	105
Izagry Phosphorus	10.06	4.3	23.06	9.0	13.07	17.8	22.07	28.1	06.08	28.9	05.09	30.4	100
Izagry Phosphorus + Rizotorfin	10.06	5.1	23.06	10.0	13.07	22.4	22.07	28.5	06.08	29.0	05.09	31.5	100
$CaSO_4 + 2H_2O_5$	10.06	5.9	23.06	12.2	13.07	20.2	22.07	24.1	06.08	25.1	05.09	25.7	105
$CaSO_4 + 2H_2O_5$ + Rizotorfin	10.06	6.2	23.06	12.9	13.07	21.0	22.07	24.9	06.08	25.9	05.09	26.0	105

Quantitative (productivity) parameters

One of the most important indicators characterizing the efficacy of the use of biological or chemical preparation is productivity (yield). It is a result of the cumulative effect of yield structural elements (Anikeyeva, 1992) (Table 9).

The results showed that the yield of both legumes was significantly higher under the traditional technology than under the zero- tillage technology (at $P<0.05$) (Table 9 and 10). The use of biological preparation Respecta in combination with Izagry Phosphorus and Izagry Phosphorus and Rizotorfin had positive impact on the biological productivity of peas and chickpeas, i.e. an increase with 4,800 to 8,000 kg*ha^{-1} compared to control variant. That confirms findings of Serekpaev (1998).

Table 9. Structural elements of pea yield in relation to variants of the experiment and the technology of cultivation, mean of 2014- 2015

Variants	Number of plants *m^{-2}	Number of pods per plant	Number of seeds per pod*plant	Weight of 1,000 seeds,g	Biological yield, kg*ha^{-1}	Increase from control, %
			Traditional technology			
Control	42.3	15.0	60.0	176.0	11.200	100
Izagry Phosphorus	46.0	27.0	108.0	227.3	16.000	142
Izagry Phosphorus + Rizotorfin	48.0	33.0	132.0	236.7	17.300	154
$CaSO_4$ +2H_2O_5	45.0	21.0	84.0	189.1	13.600	121
$CaSO_4$ +2H_2O_5+ Rizotorfin	45.0	24.0	96.0	198.2	14.300	127
			Zero- tillage technology			
Control	33.0	12.0	48.0	206.0	7.900	100
Izagry Phosphorus	42.0	24.0	96.0	224.5	12.100	153
Izagry Phosphorus + Rizotorfin	45.0	27.0	120.0	231.6	13.200	167
$CaSO_4$ +2H_2O_5	36.0	18.0	72.0	218.3	9.900	125
$CaSO_4$ +2H_2O_5+ Rizotorfin	42.0	21.0	83.0	220.1	10.300	130

These combinations provided also for the greatest differences in comparison with the control variant, i.e. almost double number of pods per plant and number of seeds per pod, and weight of 1,000 seeds. The single addition of biological soil inoculation promoter Rizotorfin under the two technologies provided for an increase of pea yield with 1,100 to 1,300 kg*ha^{-1} (Table 9), and an increase of chickpea yield with 600 to 1,200 kg*ha^{-1} (Table 10). Two-way ANOVA, StatSoft (Figure 1 and 2 below) showed statistically significant impact (at $P<0.05$) of single independent factors technology (traditional and zero- tillage) and treatment on pea and chickpea on biological yield. Under traditional technology, the yield is significantly higher than under zero- tillage in all variants. However, the interaction of the two factors did not produce significant impact on pea and chickpea yield ($P>0.05$).

Table 10. Structural elements of chickpea yield in relation to variants of the experiment and the technology of cultivation, mean of 2014-2015

Variants	Number of plants $*m^{-2}$	Number of pods per plant	Number of seeds per pod*plant	Weight of 1,000 seeds,g	Biological yield, $kg*ha^{-1}$	Increase from control, %
			Traditional technology			
Control	30.0	24.0	48.0	241.0	8.400	100
Izagry Phosphorus	36.0	33.0	66.0	280.3	15.800	188
Izagry Phosphorus+ Rizotorfin	42.0	36.0	72.0	290.4	16.400	195
$CaSO_4+2H_2O_5$	33.0	27.0	54.0	260.1	9.200	109
$CaSO_4+2H_2O_5$ + Rizotorfin	36.0	30.0	60.0	271.9	9.250	110
			Zero- tillage technology			
Control	27.0	15.0	30.0	180.0	7.600	100
Izagry Phosphorus	36.0	24.0	48.0	242.3	12.200	160
Izagry Phosphorus+ Rizotorfin	42.0	27.0	54.0	260.7	13.400	176
$CaSO_4+2H_2O_5$	30.0	18.0	36.0	196.7	7.850	103
$CaSO_4+2H_2O_5$ + Rizotorfin	33.0	21.0	42.0	224.0	8.100	106

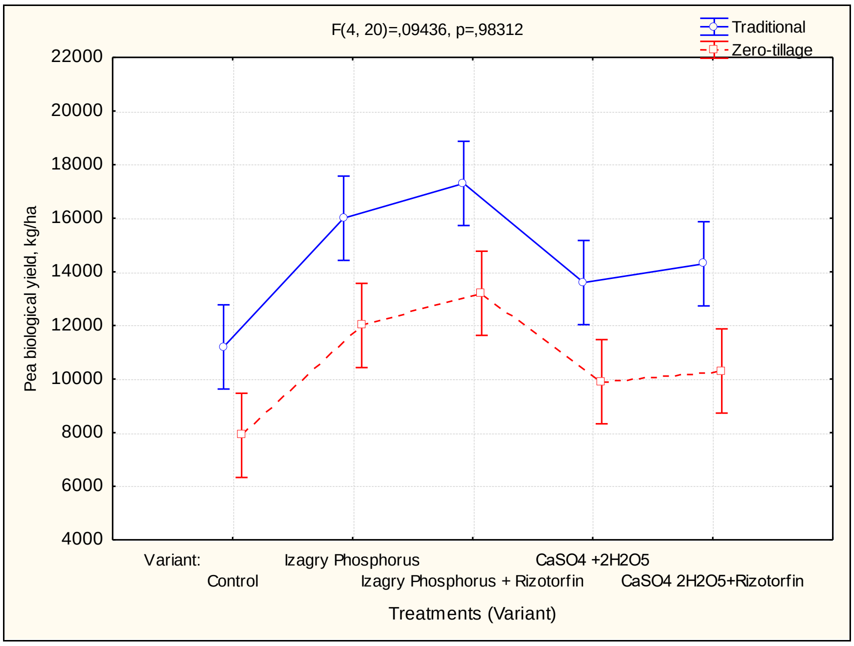

Figure 1. Effect of major factors treatment (variant) and technology (traditional and zero-tillage) on biological yield of pea, mean of 2014 and 2015.

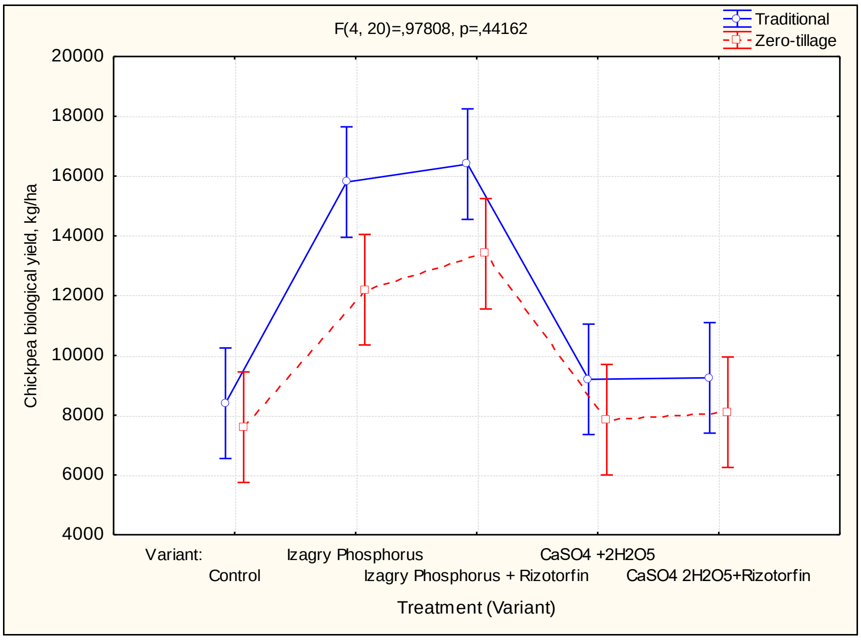

Figure 2. Effect of major factors treatment (variant) and technology (traditional and zero-tillage) on biological yield of chickpea, mean of 2014 and 2015.

Conclusions

The agroecological conditions were suitable for producing pea and chickpea. Despite the temperature fluctiations and irregular precipitations. The reserve of available moisture at harvest was 33.7 mm under traditional technology and 40.2 mm under zero-tillage technology. The soil had low nitrogen and phosphorus content in the upper layers. Under traditional technology, Cu and Zn content in soil after application of Respecta (biological preparation) and Pivot (chemical preparation) were higher than in the control variant, but were still within the MPL for Kazkhstan. The biological preparation Respecta eliminated weed pressure and reduced their negative impact on legumes' germination and growth, which were better under traditional technology. It might be attributed to better utilisation of soil air and improved soil porosity in 0 - 20 cm layer. Combinations of mineral fertilizer $CaSO_4 + 2H_2O_5$ and the innoculation promoter Rizotorfin, and Phosphorus -promoter Izagry Phosphorus and Rizotorfin may be recommended to farmers. The latter reduced the elapsing time between main phenophases and the overall length of vegetation (in days). Thus farmers may apply late sowing in spring and utilize the higher temperatures during main vegetation period. Biological productivity i.e. yield of peas and chickpeas, increased under traditional technology that seems suitable under dry steppe climate of Northern Kazakhstan.

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