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Agrotechnological methods of plant feeders applying for spring wheat agrocenoses – North-Eastern Kazakhstan varieties

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Abstract: To improve plant resistance to pests, we analysed the impact of various agronomic practices on the number and species diversity of pests in the crops of spring wheat varieties of foreign and Kazakhstan breeding in North-Eastern Kazakhstan.

The intensive development of agriculture, resulting in the new technological flow processes of wheat growing, the sowing of foreign varieties not previously cultivated under local conditions, and climate change contribute to the formation of new food chains in agrocenoses. These new food chains require the monitoring of plant-feeding species with the help of ecological approaches and techniques.

Efficient protection of crops with plant feeders requires constant updating on the phytosanitary in agrocenoses. Information on phytosanitary monitoring previously carried out in the region is not available, so it became necessary to collect data and analyse the number and species composition of wheat pests, considering new foreign varieties and cultivation technology practices.

The research was carried out in 2021 in typical agricultural organisations of the North-Eastern regions of Kazakhstan with different preceding crops. The vegetation period was characterised by high atmospheric temperatures and a lack of moisture in the soil in spring and summer, contributing to decreasing of plant turgor and damage resistance.

Early sowing of the 'Triso' wheat variety was affected by high temperatures and lack of soil moisture in the initial stage of development, which delayed its growth and made it more susceptible to pest damage. The other varieties were sown in optimal dates recommended by regional scientific institutions.

Keywords: agrotechnological practices, climatic conditions, foreign and Kazakhstan breeding varieties, pests, species composition, spring wheat

INTRODUCTION

Wheat (*Triticum* L.) is the main food grain crop in the Republic of Kazakhstan. The Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan confers that in 2020 the total gross harvest of crops reached 19,508.5 Gg, including 14,258 Gg of wheat, which is almost 73% [Agency … 2022].

Kazakhstan is a country of diverse natural conditions, including forest-steppe, steppe, semi-desert, and desert zones. The latitudinal zoning, increasing aridity of climate from west to east, geological and geomorphological peculiarities of different parts of the territory are the reasons for the diversity of soils in Kazakhstan. The key feature of the climate in Kazakhstan is a sharp continentality and aridity, which is related to the country's inland geographical location. The absence of natural barriers in the north of the country allows the continental polar air masses to penetrate freely to the southernmost outskirts. This explains rather harsh winters in most parts of the territory.

Kazakhstan is also affected by climate change. Its impact is increasingly evident, as more frequent extreme weather conditions such as drought, dry winds and dust storms may lead to an increase in the natural spread of pests with air currents.

According to a scientific review of the effects of climate change on plant pests, initiated by the FAO, rising temperatures greatly expand the range of pests, including invasive pests, which, according to the authors of the review, one warm winter is enough to facilitate their acclimatisation [IPCC Secretariat 2021a].

Thus, in such unfavourable soil and climatic conditions, cereal crop producers face the task of increasing their yields, including spring wheat, as well as meeting the needs of the population in high-quality agricultural products, thereby ensuring the food security of the country as a whole. At the same time, the reliable protection of wheat crops from various kinds of pests, which cause yield losses and quality deterioration, is of major importance.

According to FAO, up to 40% of the world's food crops are destroyed each year by pests. Thus, in the years of mass reproduction of pests, the yield of spring wheat is reduced to 23.2%; in the years of epiphytotic, the yield of spring wheat is reduced to 40.0–60.0% [Timofeyev, Perfiliev 2016]. The analysis of the presented data shows that the problem of crop protection from pests is relevant not only for Kazakhstan.

Human-induced activities have led to unfavourable conditions for entomofauna on agricultural land, which inevitably leads to a decrease in their numbers and an increase in the number of plant-feeding species adapted to the specific conditions of spring wheat agrocenoses.

According to Gaur and Magalapu [2018], wheat is one of the main cereal crops cultivated worldwide; it is consumed by about 35% of the population. Wheat is a major component of the daily diet in most developing countries. Wheat accounts for 20–60% of the daily ratio, it is necessary to constantly increase the yield and production of wheat to cope with the increasing demand [Randhawa *et al.* 2019]. Growing this crop is quite labour-intensive and is greatly complicated by several factors. Ricroch [2017] identifies the factors that have a significant impact on wheat cultivation, including insect pests, viral and fungal diseases. Biotic influences on wheat are accompanied by abiotic factors of arid environmental conditions. Because of this impact, the cultivation of transgenic plants that acquire resistance to cereal crop pests at the genetic level has acquired a significant role. However, about 20 years ago, the use of such plants ceased and the search for better pest control of cereals has resumed maximising yields [Ricroch 2017].

Wheat is constantly exposed to many biotic and abiotic stresses, which leads to huge economic losses [Kashyap *et al.* 2020]. Late sowing of crops leads to a shift in growth phases, fewer days for growth and development, effective accumulated temperature and accumulated solar radiation, which will reduce the number of grains per spike and 1000 grain weight [Zhang *et al.* 2022]. Kumar and Omkar [2018] argue that despite comprehensive crop protection measures, about 10% of cereal yield worldwide is reduced precisely because of insect pests. Sharma *et al.* [2017] estimate the annual yield losses at 18–20%, which is caused by the influence of grain pests. These figures are particularly important in emerging economies, in particular in Asia and Africa. Therefore, given the annual increase in population and the volume of crop losses, it is necessary to review methods of sustainable control of the number of grain pests [Sharma, Kooner 2017]. Out of the many causes of crop slow productivity, it is the infestation of plants by insect pests that is of particular concern [Razaq *et al.* 2019]. It is important to keep track of pests at different stages of crop development [Loseva *et al.* 2021; Shatalina *et al.* 2020; Skorokhodov, Zorov 2021]. Global losses from different categories of pests vary depending on the crop and agroclimatic conditions. Animal pests, including insects, account for 15.6% of crop losses. Insects are also carriers of various plant pathogens, which cause indirect losses amounting to 13.3% [Omkar, Tripathi 2020]. The most common insect pests are wheat aphids (Hemiptera: Aphididae), including *Sitobion avenae*, *Schizaphis graminum*, *Rhopalosiphum padi*, and *Metopolophium dirhodum* [Liu *et al.* 2020]. Seeds are a haven for many pests that feed on them and affect their germination [Agrawal *et al.* 2020]. Most pests that cause seed loss belong to the Coleoptera, as well as some species of Lepidoptera, Diptera, Psocoptera, and Hymenoptera [Rezaei *et al.* 2020]. Such factors as frequent rainfall, abrupt temperature changes, cool and prolonged spring, and pre-sowing treatment of seeds with insecticides and fungicides restrain the development and spread of pests. Dinasilov *et al.* [2019] conducted monitoring and protective measures on the fields of "Agropark Ontustik" LLP that helped establish that seed dressing inhibited the development and spread of pests such as Sunn pests, leeches, cereal chafers, wireworms, and false wireworms.

Climatic conditions have a significant impact on the cultivation of cereal crops. Ali *et al.* [2017] give special importance to the concentration of carbon dioxide, temperature increase, and aridity. Schierhorn *et al.* [2021] note that each of these factors, to a certain extent, has a significant impact on wheat crops during a certain stage of their development, which forms future yield volumes. An alternative type of wheat better adapted to high temperatures and semi-arid climate is durum wheat (*Triticum turgidum* ssp. *durum*). The main centers of its cultivation are the Mediterranean and Canada, producing about 60% of the total volume of this type of wheat. However, despite its relatively high adaptability to drought conditions, its cultivation is also threatened by climatic environmental conditions [De Vita, Taranto 2019]. Wheat is also one of the dominant species of cereal crops in South Africa, where the main pests of those are nematodes *Meloidogyne*, *Longidorus*, *Nanidorus, Paratrichodorus*, and *Xiphinema*, which are controlled by nematocides, the low effectiveness of which has been explained by scientists. Thus, McDonald *et al.* [2017] found that the main reason for the low effectiveness of nematocides was partly due to weather and climatic conditions, namely, due to fluctuations of the rain regime.

Nawaz *et al.* [2019] focus on the fact that for effective pest control of cereal crops it is important to consider the time, place of use of the chemical, and the pest strategy. At the same time, such integrated pest management may help to reduce yield losses without harming non-target organisms. Khan *et al.* [2019] believe that the use of tillage methods and planting dates, various traps and intercrops, and plant extracts helps to reduce the infestation of wheat and other cereal crops by pests. Still, their efficiency will be tangible only when using a set of methods and minimising the use of chemicals in the process]. Other researchers use the method of biological control, which is the use of natural enemies to reduce the population density of insect pests as the main method of pest control of grain crops [Saleh *et al.* 2017; Verma *et al.* 2019]. To manage wheat resistance to insect pests, resistance genes (R-genes) have been identified in varieties with resistance, which are highly effective and are actively incorporated into wheat varieties through breeding [Iftikhar *et al.* 2019]. Veselova *et al.* [2019] and Khairullin *et al.* [2021] offer to use the bacteria *Bacillus subtilis* Cohn and *Bacillus thuringiensis* Berliner for the control of common cereal aphids. Using chitosan and its oligomers may ensure the safety of wheat crops from septoriosis infection [Shagdarova *et al.* 2018]. Application of a proper crop rotation regime, in turn, can ensure a reduction in wheat infestation by cereal crop pests by more than 50% [Fanadzo *et al.* 2018; Zohry, Ouda *et al.* 2018], which will significantly reduce yield losses and, consequently, grain storage losses [Tripathi 2018]. Also, according to Li *et al.* [2020] for sustainable management of local ecosystems it is necessary to take into account three main aspects of diversity: genetic, species, and ecological.

At the same time, climate change will have a significant impact on crop yields, since by increasing the temperature regime, there will be an acceleration of wheat growth stages [Valizadeha *et al.* 2014].

Analysis of literary sources highlighted the fact that the protection of wheat crops from plant-feeding species is relevant not only for Kazakhstan but also for other countries involved in the production of this crop. At the same time, methods of control are selected following the peculiarities of the climate and safety issues for living organisms.

Intensifying agricultural activity has accelerated the adaptive variability of pests and their rapid reproduction. Plant feeders do not need to expend large amounts of energy to find food, while grain crops (spring wheat) are more nutritious than wild cereals. As a result, the natural balance between harmful and beneficial species is disturbed; plant-feeding insects often proliferate in mass numbers. The use of chemical pesticides as a control method creates unfavourable conditions for the entomofauna, which inevitably leads to a decrease in their numbers. As a result, the natural balance between harmful and beneficial species is disturbed and plant-feeding insects often proliferate in mass numbers because of their potential for acquiring resistance. Thus, there is currently insufficient information regarding the impact of changing climatic conditions on the effectiveness of protection methods, especially chemical and biological measures [Delcour *et al.* 2015; Gilardi *et al.* 2018].

For example, the switching to resource-saving technologies in steppe conditions with preservation of crop residues and saturation of crops, mainly spring wheat, creates conditions for the development and dominance of resistant pest populations with a long biological cycle.

Therefore, to obtain high productivity and profitability of spring wheat grain, it is important to improve the phytosanitary condition of the crop. It is equally important to obtain environmentally friendly products that are safe for the population.

The increasing spread of organic production in the world, which implies abandoning synthetic pesticides, urges us to find ways of protecting plants from pests, taking into account ecological approaches that establish a balance between the pest and the entomofauna. In this case, biological and agrotechnical techniques of plant feeders' regulation seem advantageous.

According to the International Plant Protection Convention (IPPC) Strategic Framework 2020–2030, strategies for intensifying crop production and pest control must be more sustainable than those currently in use. They should be based on integrated plant protection, biological pest management, conservation agriculture, sustainable use of plant genetic resources, and reduction of soil, air and water pollution [IPCC Secretariat … 2021b].

To prevent losses of spring wheat yield from pests, a constant update of information on the patterns of phytosanitary situation formation in agrobiocenoses is required, as it is the basis for planning and organising protective measures.

There is no information on phytosanitary monitoring previously carried out in the region's conditions, so, there arose a need for data collection and analysis of the number, and composition of wheat pest species, taking into account changing climatic conditions, new foreign varieties and cultivation technologies.

Properly selected cultivation practices such as the preceding crop, varieties, and sowing dates are also important for increasing plant resistance to pests. Of all agronomic practices used in the regions, we studied those that have a greater influence on the number of phytophages in wheat crops. One promising way to control pests is to select wheat varieties that are resistant to their impact, as varieties respond differently to pest damage: some drastically reduce productivity, while others are not affected. For example, this can be observed well in sucking insects such as aphids and bugs. The corn bug is less damaging to the fast-maturing varieties [Sagitov, Ismukhambetov 2004]. In addition, local producers choose not only Kazakh breeding wheat varieties, but also highly productive foreign breeding ones, which are not adapted to unfavourable soil and climatic conditions of the region and local plant feeders.

Using such techniques as crop rotation and the timing of sowing also allows us to effectively influence the conditions of pests, thereby reducing yield losses and reducing its quality caused by plant-feeding species. For example, by changing the timing of sowing a crop with respect to the climatic factors during the growing season, it is possible to reduce the degree of damage to plants in their most vulnerable phases during the mass appearance of the pest. Studying different preceding crops allows selecting the best ones in a given area, the ones that would create the worst conditions for wintering and development of pests, reducing their total number. At the same time, the effect of this or that agronomic technique in different agro-climatic zones may be manifested differently. Therefore, the choice of agronomic techniques must take into account the soil and climatic characteristics of a particular area, or even a particular farm, the common wheat feeding species.

Thus, our objective was to carry out a comparative analysis of the impact on the species composition and number of pests of different agrotechnological methods and climatic conditions during the growing season inagrocenoses of spring wheat varieties of foreign and Kazakh breeding in the North-Eastern Kazakhstan (using Pavlodar region as a case).

To achieve the goal the following objectives were set: to assess the impact of spring wheat varieties and climate conditions on the diversity and number of plant feeders in crops, to analyse the effect of early and recommended sowing dates, as well as different preceding crops on the population of agrocenosis by grain crop pests.

MATERIALS AND METHODS

MATERIAL

The study focused on various agro-technological practices affecting plant-feeding species in agrocenoses of spring wheat varieties. Studies were carried out according to the generally accepted pest control methods in grain crops.

METHODS

The study period included phenological observations of crop development stages. The stages are: sprouting, tillering, stem elongation, earing, flowering, kernel milk line, middle dough, and full-ripe stage. Entering the stage by 10–15% of plants was marked as its beginning, while 75% of the total number of plants meant that the stage was complete.

We determined the biometric parameters of the crop before harvesting using a ruler: plant height (from the soil surface to the top of the ear), ear length, and grain size. Measurements were carried out along the diagonal of the plot of 10 plants in the first and third replications.

Meteorological data were recorded according to the information of local weather stations (from May to August 2021): daily maximum, average and minimum air temperature, rainfall per day, maximum, average, and minimum relative humidity during the day.

Pests were counted using quantitative methods [Moskvichev *et al.* 2015; Polyakov *et al.* 1984].

Relatively large and sedentary pests living on plants and in the soil were enumerated at discount areas. A light frame 50 cm in length and 50 cm in width was placed on the soil surface to count the number of species that were on plants and fell on the soil (within the area bounded by the frame). This method was used for counting sunn pests (*Eurygaster integriceps*), cereal chafers (*Anisoplia austriaca*, *Anisoplia agricola*), corn ground beetles (*Zabrus tenebrioides*), meadow moth caterpillars (*Loxostege sticticalis*), and many others.

We used an aerial insect net to count pests in the upper layer of the grass stand. A standard net (hoop diameter 30 cm, receiving bag depth 60 cm, handle length 1 m) was used. The net was swung 10 times over the upper part of the grass stand without interruption. Then its contents were transferred from the net and the number of insects was counted. Ten series of sweeps were made so that their total number reached 100 in several places of the study area. Wheat thrips (*Haplothrips tritici*), wheat flies (*Phorbia fumigata, Chlorops pumilionis, Meromyza nigriventris* and others), leafhoppers (Cicadellidae), bread fleas (*Phyllotreta*), and many others were counted this way.

Infestation of plants by the bread flea was evaluated in each field in ten places by checking ten plants and evaluating the degree of leaf surface devouring by the fleas on a five-point scale: 0–5% was scored as 1 point; 6–25% as 2 points; up to 50% as 3 points; up to 75% as 4 points; 76–100% as 5 points.

Insect identifiers were used to clarify the species identity of the detected insects.

NATURE OF THE VARIETIES UNDER STUDY

Spring wheat varieties of foreign breeding (‘Likamero’, ‘Triso’, ‘Uralosibirskaya’, ‘Omskaya 35’) and Kazakh breeding (‘Kazakhskaya 15’) were selected for the study. The information on the varieties is taken from GlavAgronom [undated].

Foreign selection varieties ‘Likamero’ and ‘Triso’ have recently attracted interest among grain producers in Northeast Kazakhstan for their ability to withstand short-term low temperatures and rapid development in the initial period, which allows them to sow in earlier terms, when moisture reserves in the soil are still sufficient, as moisture deficit is the main limiting factor in the region.

‘Likamero’ variety breeder is Secobra Recherches (France); its parentage is (Hanno × Devon) × (STRU689 × Quattro). The variety is lutescens. This variety is characterised by rapid development in the early phases, good resistance to lodging, very high resistance to spikelet fusariosis, root rot, powdery mildew, and brown rust is affected poorly, high protein content in the grain. This is a compensatory type, which forms its harvest by having a high ear and 1000 grains weight, the vegetation period is 72–97 days, it is moderately drought-resistant. Baking qualities are good, can be sown in early terms, not afraid of early spring frosts.

The breeder of the ‘Triso’ variety is Deutsche Saatveredelung AG (Germany); its parentage is Kadett × Weihenstephan Stamm. Variety is lutescens. This variety is characterised by good lodging resistance, the vegetative period is 85–90 days, baking quality is good, moderately susceptible to brown rust, powdery mildew, strongly susceptible to smut. Variety intensive type, double-root, that is, when sown in the fall, develops as a winter form, when sown in spring as spring, which provides the variety with high adaptive properties. It can be sown as early as possible to achieve high tillering, the variety is not afraid of frost.

The breeder of the ‘Uralosibirskaya’ variety is FGBNU “Siberian NIISKh” (Rus. Federal'noye gosudarstvennoye byudzhetnoye nauchnoye uchrezhdeniye «Sibirskiy nauchno-issledovatel'skiy institut sel'skogo khozyaystva Sibirskogo otdeleniya Rossiyskoy akademii sel'skokhozyaystvennykh nauk») and LLC “Agrocomplex ‘Kurgan Semena’” (Rus. Obshhestvo s ogranichennoy otvetstvennost'yu «Agrokompleks «Kurgansemena»») – Russia. Variety is lutescens. The vegetation period is 78–93 days, drought tolerance is good. It is moderately susceptible to leaf rust, powdery mildew, and root rot. In the field conditions, it is strongly affected by dust bunt and septoriosis.

‘Uralosibirskaya’ variety has increased resistance to adverse environmental factors, thanks to the thick straw, has a high resistance to lodging, a high percentage of preservation of the stem.

The breeder of the ‘Omskaya 35’ variety is FGBNU “Omsk Agrarian Scientific Center” (Rus. Federal’noye Gosudarstvennoye byudzhetnoye nauchnoye uchrezhdeniye). The variety is *lutescens*. Its vegetation period is 87–90 days. Resistant to lodging, moderately drought tolerant. Moderately susceptible to brown rust, susceptible to dusty mildew, strongly susceptible to hard knotweed, stem rust, powdery mildew, root rot.

The ‘Omskaya 35’ variety has a high potential yield and forms high-quality heavy grains. Thanks to the high productivity in combination with resistance to diseases and lodging, this variety can successfully compete with varieties of similar ripeness groups.

The breeders of the 'Kazakhstan 15' variety are LLP "Kazakh Research Institute of Agriculture and Crop Production" (Rus. TOO «Kazakhskiy nauchno-issledovatel'skiy institut zemledeliya i rasteniyevodstva») and LLP "Pavlodar NIISKh" (Rus. TOO «Pavlodarskiy nauchno-issledovatel'skiy institut sel'skogo khozyaystva») (Kazakhstan). Variety is lutescens. The vegetation period is 85–90 days. It is resistant to lodging, preharvest germination of grain. The variety is resistant to drought and brown rust [GlavAgronom undated].

CLIMATIC FEATURES OF THE STUDY AREAS

Pavlodar region is marked by a significant diversity of natural conditions. It is located mainly within two natural zones of steppe and desert-steppe [Samokhvalov 1958].

For phytosanitary monitoring, we selected the main wheat cropping areas in different parts of the region (Zhelezin District, Uspen District, and Ertis District), which differ in climatic conditions, vegetation, and geological structure, which determine the corresponding diversity of soil cover.

Zhelezin District is located in the northern part of the Pavlodar region. The area is marked by low rainfall and low relative humidity in spring and the first half of summer, maximum rainfall in midsummer, high summer and winter temperatures, late spring and early fall frosts, and high wind activity during the year. The minimum temperature is in January–February, where the average temperature in January is minus 18–19°C. The maximum temperature is in June–July, where the average temperature in July is plus 19–20°C. The average annual rainfall is 275.5 mm, sometimes more than 300 mm.

Vegetation is represented by forb-feather associations; there are some aspen and birch forest outliers. Soil covering is represented by southern blacksoil, more often they are solonetzic and solodised, forming complexes and combinations with solonetz and meadow-chernozemic solonetzic soils, occurring in depressions. The presence of complexes with solonetzic soils creates heterogeneity and spotting of the fields, which leads to the uneven appearance of seedlings and thinning of crops.

Uspen District is located in the north-eastern part of the Pavlodar region. The climate of the area is marked by a sharply arid spring and the first half of the summer. The average January temperature –19.6°C, July +19.6–21.4°C, the amount of rainfall averaged 260–310 mm per year, most of which falls in the second half of summer, so growth and development of culture are largely determined by the amount of moisture stored before sowing.

Soils of the district are dark-chestnut soils of light granulometric composition in the complex with solonetz and meadow-chestnut soils. It has fescue-feather, vermouth, and vermouth-feather vegetation.

Ertis District is located in the north-western part of the Pavlodar region. Features of the climate are a short spring and autumn, with extremely unstable temperature, with sharp fluctuations from warm to cold, and often from hot to freezing, hot and dry summer, the amount of rainfall averages 250–310 mm. The average temperature of January –18°C, July +20°C.

Soils are chernozemic and chestnut, loamy, sandy loam, and sandy in granulometric composition, solonetzic complexes are also widespread. It has fescue-feather-vermouth vegetation.

STATISTICAL ANALYSIS

Statistical data processing was carried out using Microsoft Excel 2007. Pearson correlation coefficients, errors, and criteria for the significance of the correlation coefficient were calculated to assess the relationship between climatic factors during the growing season and the number of plant-feeding species in wheat crops. Differences were considered statistically significant at the $p < 0.05$ level.

RESEARCH PERIOD

The studies were carried out during the growing season of 2021 in typical agricultural organisations in the Pavlodar region (North-East of Kazakhstan) for various preceding crops (complete fallow, spring wheat, and flax).

AGRICULTURAL TECHNOLOGY USED IN THE STUDIED FIELDS

Soil preparation for complete fallow and spring wheat preceding crops differ significantly; multiple tillage in complete fallow creates better conditions for growth and development of subsequent crops, but worsens conditions for feeding and overwintering of phytophages, unlike spring wheat fields, where many crop residues remain on the surface, which pests use for wintering. Oilseed flax (*Linum usitatissimum* L.) as a preceding crop is noteworthy as this crop is new for the region and the issues of its influence on accumulation and distribution of pests are insufficiently studied.

In the Zhelezin District, the following fields were examined: 16(1), field area 201 ha, the preceding crop is complete fallow (2020) and 57, field area 282 ha, the preceding crop is spring wheat (2020).

Sowing on the field 16(1) was carried out on May 15; agricultural technology is generally accepted for this region; the variety is 'Likomero'. The North-East of Kazakhstan is characterised by strong wind erosion of soils, so the main technology of tillage is a subsurface loosening, which prevents wrapping of the arable layer and leaves on the surface of the crop residues.

Sowing on field 57 was carried out on May 24; direct sowing on a stubble background; 'Uralosibirskaya' variety.

In the Uspen District, we examined the following fields: 65 (Lozovoye), the field area is 495 ha, the preceding crop was spring wheat (2020), and 65 (the village of Kovalevskoye), the field area was 516 ha, the preceding crop was complete fallow (2020).

Sowing on field 65 (Lozovskoye) was carried out on April 28; agricultural technology is generally accepted for this region; the wheat variety is 'Triso'.

Sowing of field 65 (Kovalevskoye) was carried out on May 18; agricultural technology is generally accepted for this region; the wheat variety is 'Omskaya 35'.

In the Ertis District, the following fields were examined: 31, the field area was 372 ha, the preceding crop was spring wheat (2020) and field 50, the field area was 307 ha, the preceding crop was flax (2020) (Agashoryn).

Sowing on-field N31 was carried out on May 5; agricultural technology is generally accepted for this region; the wheat variety is 'Trizo'.

Sowing on field 50 was carried out on May 21; agricultural technology is generally accepted for this region; the wheat variety is 'Kazakhstanskaya 15'.

RESULTS

In the ongoing research in 2021, the complex of dominant pests for crops of spring wheat varieties of foreign and Kazakh breeding included wheat thrips (*Haplothrips tritici*), grain flea beetles (*Phyllotreta vittula*), stem flea beetles (*Chaetonema aridula*), bugs (*Trigonotylus ruficornis*), wheat aphids (*Schizaphis graminum*), and leafhoppers (*Psammotettix striatus* L.). Yet their distribution in general over the study areas and for different preceding crops is uneven. At the same time, the domination of sucking insects was noted, which may be explained by climatic conditions: in recent years, as well as in 2021, there was an increase in air temperature and lack of rainfall during the growing season of the crop, under such conditions, plants lose turgor and become more susceptible to sucking insects. Other types of pests were found in small quantities; there was no severe damage to plants. The main pest species more often found in crops are members of the family Locusts (Acridoidea), meadow moth (*Loxostege sticticalis*).

Phytomonitoring of wheat agrocenoses in Zhelezin District for the preceding crop complete fallow (No. 16(1)) in the initial period of crop development shows no signs of infestation by phytophages; mainly small damages (less than 5%, 1 point) done by grain flea beetle (*Phyllotreta vittula*) is present. As plants develop further, during the stem extension phase, active infestation of crops occurs due to soil warming and emergence of beetles from their wintering places (10–15%, 2 points). During the same period, images of wheat thrips (*Haplothrips tritici*) appeared on plants, ranging from 2 to 7 eggs per stem. Thrips larvae and imagoes reached their maximum number by the grain filling stage (31.8% of total number of grain phytophages) because during this period nutrients were actively delivered to grain in a form accessible to larvae. There is also an increase of stem flea beetles (*Chaetonema aridula*) (63.7%); its maximum number was observed only in this area, which is explained by the nearby location of their wintering places (forests).

The distribution of pests by stages of crop vegetation is shown in Figure 1a.

At the end of the crop vegetation there was a 51.5% decrease in the number of phytophages associated with the migration of many species to nearby stations in search of food. The plant height of the variety 'Licomero' averaged 78 cm, the ear length was 7–8 cm, the grain was heavy and large.

No pests were found in the area of spring wheat (No. 57) at the initial stage of vegetation. Only at tillering stage, slight injuries caused by flea beetle was 5% (1 point); imagoes of wheat thrips numbered 4–5 specimens per stalk. Polyphagous and associated pests were found in small numbers. In this area, as in field No. 16 (1), grain pests increased up to 92.7% (Fig. 1b) with the predominance of wheat thrips (*Haplothrips tritici*).

With the completion of crop development, the number of grain phytophages decreased by 44.1%. The main share of pests accounted for: wheat aphid (*Schizaphis graminum*) (29.1%), grain flea beetle (*Phyllotreta vittula*) (17.4%), small brown planthopper (*Laodelphax striatella*) (17.4%), leaf bug (*Trigonotylus ruficornis*) (18.6%), which mainly fed on the plants lagging in development. The height of plants of the 'Uralosibirskaya' variety was 58–91 cm, the length of the ear was 5–8 cm, the grain was medium-sized.

In Uspensky area in field No. 65 (Lozovskoye) the early sowing of culture resulted in the yellowing of leaves due to high temperatures and lack of moisture in the soil, which made the plants more susceptible to damage by the grain flea beetle (*Phyllotreta vittula*) (5–10%, 2 points). When the ear was forming, active infestation by imagoes of wheat thrips (*Haplothrips tritici*) was observed: 10–15 plants per ear with 15–20 damage per ear (see Fig. 1c), while their number was the highest before the kernel milk stage. As the plants at early sowing date fell into unfavourable conditions for growth and were strongly affected by sucking insects weakening them, by the end of vegetation the height of the wheat variety 'Triso' was 30–37 cm, the ear length was 4–5 cm, the grain was small and incomplete. Wheat aphid (*Schizaphis graminum*) (39.2%) and leaf bug (*Trigonotylus ruficornis*) (25.6%) were also observed in the crops; the other species were found in single specimens.

In field No. 65 (Kovalevskoye), under bare fallow, crops were sown at a later date, which resulted in low numbers of phytophages during the initial phases of wheat development; as crops developed, pests were found in small numbers: the grain flea beetle and imagoes of wheat thrips amounted by 2–3 pieces per stalk (Fig. 1d).

The maximum number of phytophages was detected in the phase of ear formation and ear ripening with the predominance of grain flea beetles (*Phyllotreta vittula*) (36.2%) and wheat thrips (*Haplothrips tritici*) (56.5%). If the number of phytophages exceeds the threshold of economic harmfulness at the vulnerable phase, it is necessary to apply chemical protection against a particular pest, taking into account the instructions for its use.

The height of plants of 'Omskaya 35' varied from 52 to 60 cm, ear length was 6.5–7.0 cm, the grain was medium-sized. The number of grain phytophages decreased to 61.7% of the total number of tested insects, but the number of entomophages increased to 26.9%, including Coccinellidae (47%) and Miridae (47%). Wheat thrips (*Haplothrips tritici*) amounted to 39.5% and leaf bug (*Trigonotylus ruficornis*) to 10.3%; they fed on plants and green parts of wheat.

In Ertis District, field No. 31 (spring wheat preceding crop) showed strong injuries caused by grain flea beetles (*Phyllotreta vittula*) (up to 50%, 3 points) during early phases of crop development. It was boosted by high air temperature during this period (20–29°C) and early sowing date (May 5) of wheat, coinciding with period of mass appearance of the beetle from their wintering grounds. During the ear formation period, imagoes of wheat thrips (*Haplothrips tritici*) infested plants (2–4 eggs per stem).

During vegetation, the yellowing of leaves and decrease in turgor on plants caused by high temperatures and low air humidity make the crop less resistant. The number of grain pests during this period increased and amounted to 92.7%, of which a significant part was accounted for the grain flea (*Phyllotreta vittula*) – Figure 1e.

At full maturity, the height of 'Triso' plants varied from 10 to 30 cm, spike size averaged 6 cm, the grain was small and incomplete. The number of grain pests significantly decreased to 23%, but the grain flea beetle (*Phyllotreta vittula*) remained dominant among them (54%).

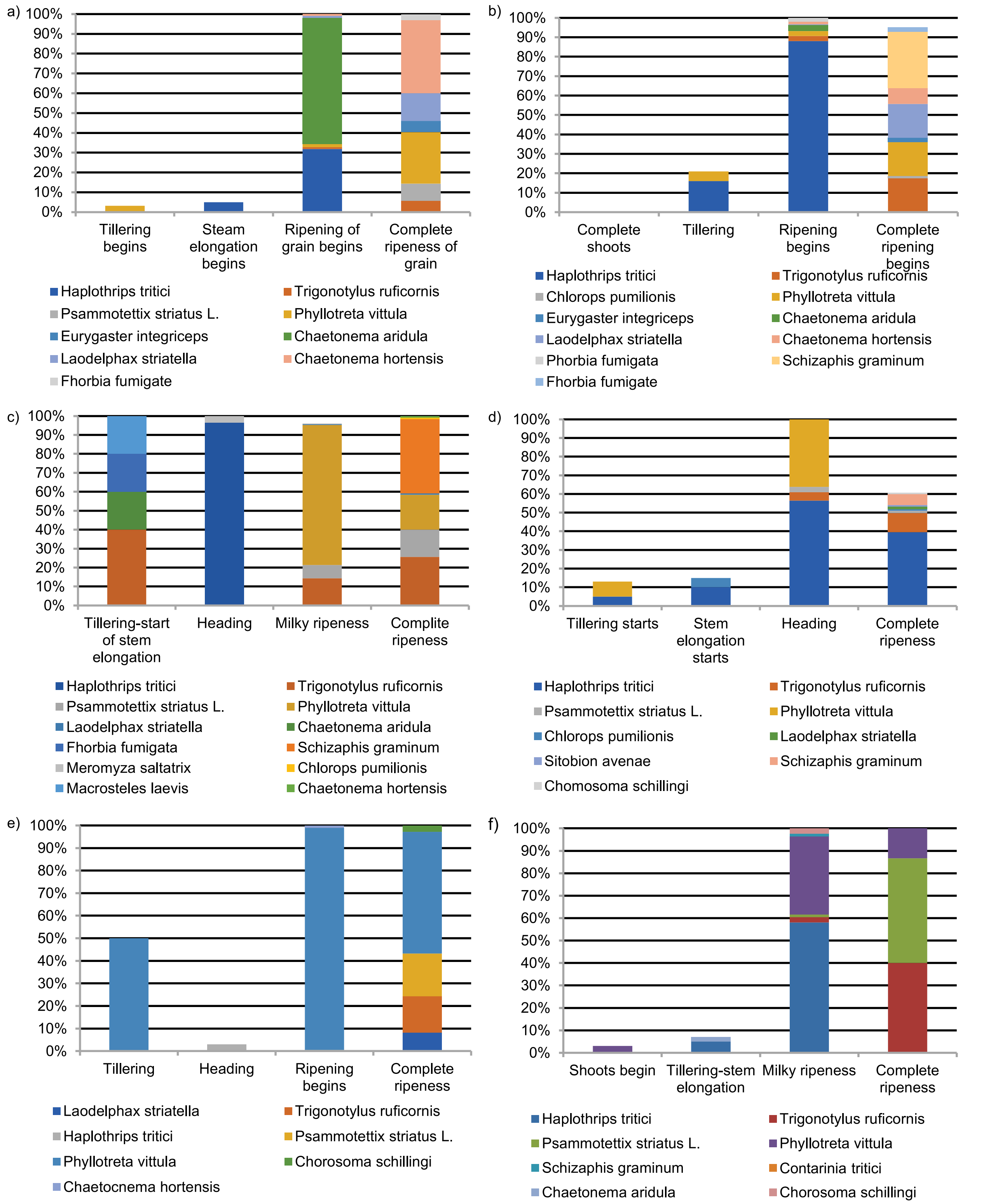

Fig. 1. Dynamics of numbers of pest species (in %) of wheat by phases of crop vegetation in 2021: a) field No. 16(1), Zhelezin District, b) field No. 57, Zhelezin District, c) field No. 65, Lozovskoye, Uspen District, d) field No. 65, Kovalyovskoye, Uspen District, e) field No. 31, Irtyshsky District, f) field No. 50, Irtyshsky District; source: own study

At the moment of observations at field No. 50 (oilseed flax preceding crop) we observed 7 specimens of *Phyllotreta vittula* per 1 m^2, but mass invasion of crops has not yet occurred due to the early phase of crop development.

Wheat thrips (*Haplothrips tritici*) appeared on plants at the stem-extension stage (2–7 eggs per 1 ear). Chemical treatment with insecticide was carried out on 24th Jun 2021. Therefore, the number of grain pests was not high, reaching its maximum at the kernel milk stage (83.5%) – Figure 1f.

At the full-ripe stage, plant height varies from 60 to 76 cm, the length of the ear is on average 6.0–7.5 cm, the grain is of medium size; there are thrips larvae in the ear 5–10 species per

1 ear (on plants at the middle dough stage or lagging in development). There is a decrease in the proportion of grain phytophages, with the predominance of leaf bugs (*Trigonotylus ruficornis*) and leafhoppers (*Psammotettix striatus*). There is also an increase in entomophages up to 21%, of which 97% are coccinellids (*Coccinellidae*). In general, in all areas of the study, mainly two-spot (*Adalia bipunctata*), seven-spot (*Coccinella septempunctata*), and Asian ladybugs (*Harmonia axyridis*) were found.

There is also a large number of flea beetles (*Aphthona euphorbiae*), which is 51% of the total number of all insects since the flax was the preceding crop. This contributed to the accumulation of its specialised pests on the field.

Comparing the stages of development of spring wheat with the number of phytophages during these periods showed that from the emergence of seedlings to the stem-extension there is an active infestation of plants in the region by the grain flea beetle and stem-boring pests.

In the conditions of North-Eastern Kazakhstan, the appearance of early wheat sprouts coincides with the mass emergence of beetles from wintering and their invasion of the crop. The beetles' damage first the leaf tips and then the entire leaf plate, which leads to the drying and falling off of leaves, thus reducing the assimilating surface of leaves and crop productivity. Crops are formed partly thinned and not aligned in height, which affects the undersupply of the grain of the crop. In addition, damaged plants become susceptible to diseases and less resistant to damage by cereal flies. The degree of damage to plants depends on the location of crops, the closer they are to pest habitats, the more severe the damage. Owing to the presence of plant residues in fields after harvesting (without plowing), the insects often hibernate under them, accumulating on the fields.

The number of large stem flea beetles (*Chaetonema aridula*) was not numerous by regions as a whole, only in field 16(1) in Zhelezin District their number at the grain filling stage was 63.7%, which is explained by proximity to the fields of forest patches and glades, places of flea overwintering. The stem flea beetles cause significant harm at the tillering, stem elongation, and earing stages of spring wheat development. Stems damaged by the larvae do not form ears; plants stop growing, thus reducing yields. Damage during ear emergence causes white spike and lodging of stalks. During the later stages of wheat development, plant damage is rare and does not significantly reduce yield [Fisechko 2014]. Damage caused by stem flea is more harmful in dry years with warm early spring, which is associated with the early emergence of adult species from their wintering places and their flight to the wheat sprouts.

At the same time, such elements of yield structure as seedlings density and productive bushiness of plants decrease. From stem-extension to ear emergence there is a mass invasion of crops by sucking pests (images of wheat thrips, leafhoppers, grain flea beetles and wheat aphids).

Observations showed that wheat thrips (*Haplothrip stritici*) dominated in all study areas, as their numbers were influenced by climatic factors during the crop vegetation period (May–August), such as average monthly rainfall and average monthly air temperature. In the beginning of crop development, the amount of thrips on wheat plants was low (3–7 pcs. per 100 swings of the net). At the beginning of the third decade of June, abundant rainfall (77.2–99 mm) was registered, which reduced thrips numbers on plants, because a negative connection between rainfall intensity and the number of phytophages was established ($r = -0.64 \pm 0.25$, $p < 0.05$, Zhelezin District). When defining the coefficient of determination ($r^2 = 0.41$), we found that the effect of rainfall during the growing season on thrips abundance is not strongly pronounced. After that, significant increase of thrips number is noted in July (up to 100–200 pcs. per 100 swings of the net), because the amount of rainfall was much lower in this month and amounted to 10.5–11.6 mm depending on the area of study. Mean monthly air temperature increased to 20.9–22.1°C, which was 3.4–4.8°C higher than in June. We established a significant positive relationship between air temperature and number of thrips ($r = -0.86 \pm 0.30$, $p < 0.05$, Zhelezin District), coefficient of determination $r^2 = 0.74$, which also indicates a high influence of air temperature on number of thrips (Fig. 2).

This period sees the hatching of larvae. Young larvae immediately begin feeding in the flowering part of the spikelet under the flower scales. The choice of feeding place is not accidental; it is in the flowering part that the plastic substances flow. The intensity of feeding of larvae increases, as the grain filling and kernel milk line stages, approach. During this period, fats and proteins in the aleurone layer are in emulsified state and are available to the larvae. At the beginning of the middle dough stage, when the process of transformation of plastic substances into stocks begins, some of the larvae stop feeding and leave the ear.

Population dynamics of *Haplothrip stritici* depending on sowing date and variety is shown in Figure 3. It was established that when crops were sown from May 15 and later, regardless of variety, the number of *Haplothrip stritici* was highest in July (102–203 individuals per 100 swings of net). Apparently, this timing of sowing coincides with the period of larval hatching and with the most favourable feeding phase of wheat: grain ripening and milky ripeness. At earlier sowing dates (April 28 and May 5), infestation by thrips was small (up to 50 eggs per 100 sweeps), but significant leaf damage by the grain flea beetle was noted in Ertis District when sowing 'Trizo' on May (*Phyllotreta vittula*).

Grain bug (*Trigonotylus ruficornis*) is found in large numbers in spring wheat crops due to its plasticity. It injures during the whole vegetation period of a crop; its characteristic damage is discolouration of the bug puncture sites because it sucks the plant cell sap, which leads to reduction of assimilating tissue and deformation of grain [Sagitov, Ismukhambetov 2004]. The harmfulness of bug borers increases in dry years when wheat crops are weakened because of the lack of moisture and high air temperatures. Weather conditions of May and summer months of 2021 in the region were characterised by high temperatures and lack of rainfall during the wheat growing season, which contributed to an increase in the number of grain aphids, which was the greatest during the period of grain ripening.

Wheat aphids (*Schizaphis graminum*) pose a great danger to wheat crops, as they can infest leaves and ears in numerous colonies in a short time, feeding on cell sap and significantly reducing grain yield. Wheat aphids were found in wheat crops during the observation period. It belongs to non-migratory species; its development occurs without changing fodder plants and occurs entirely on leaves of cereal crops.

Leafhoppers (*Psammotettix striatus* L.) are closely related to cereal vegetation. Their numbers increase in the first half of summer, during tillering and booting of wheat; their numbers are

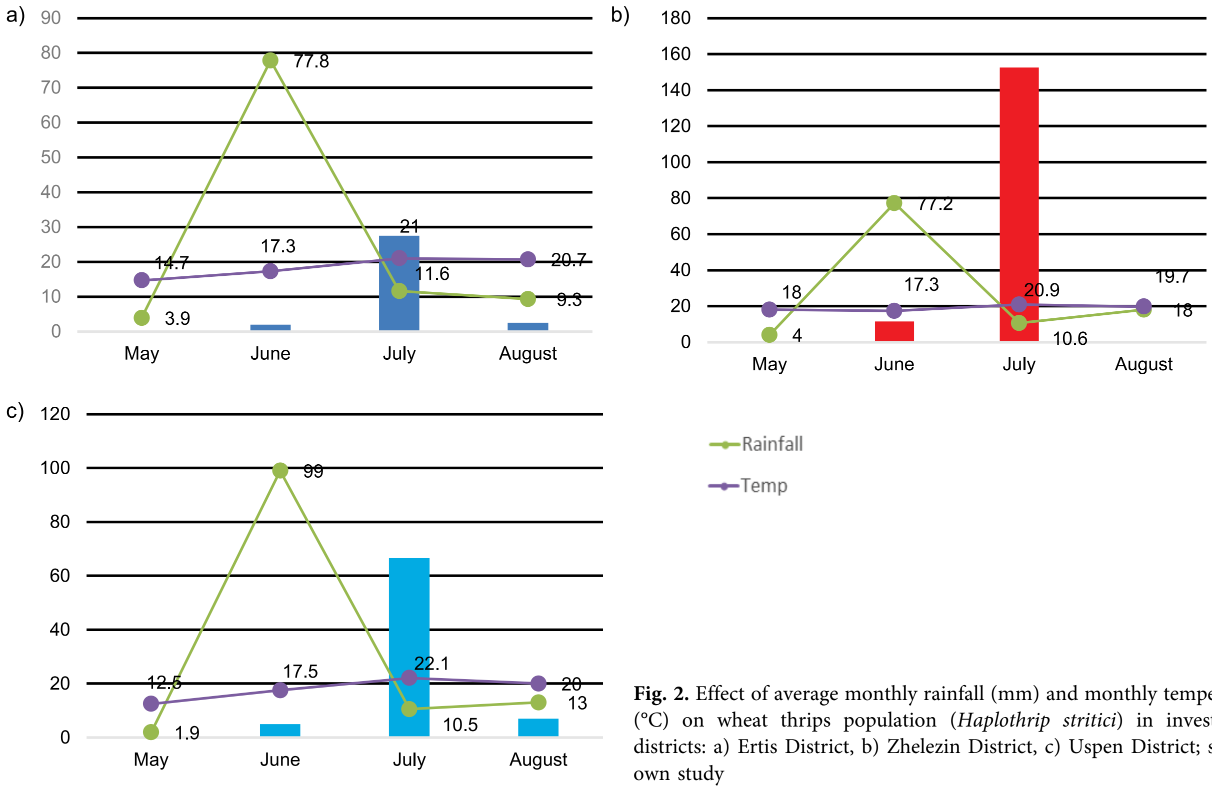

Fig. 2. Effect of average monthly rainfall (mm) and monthly temperature (°C) on wheat thrips population (*Haplothrip stritici*) in investigated districts: a) Ertis District, b) Zhelezin District, c) Uspen District; source: own study

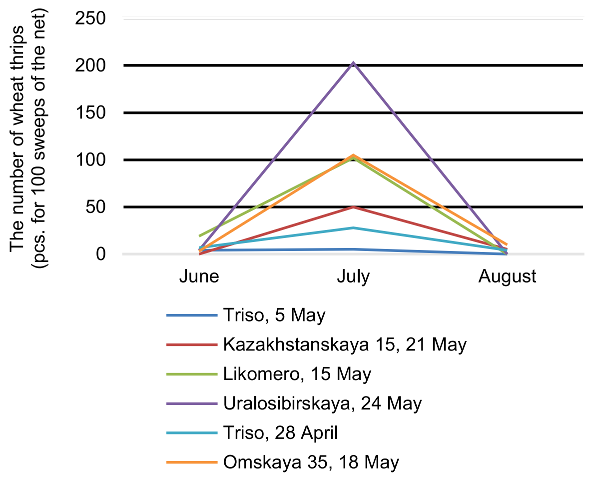

Fig. 3. Effect of sowing dates of different spring wheat varieties on wheat thrips (*Haplothrip stritici*) numbers (June–August 2021); source: own study

also high during the formation and ripening of the grain. Both adults and larvae cause damage by feeding on the cell sap of leaves and stems; whitish spots appear in stinging sites, giving damaged organs a marbled colouration.

This period of crop development is characterised by intensive growth of biomass and ear formation, so damage to plants by these phytophages will reduce crop yield by reducing the number of grains in the ear.

The most dangerous for yield formation is the period from the grain filling stage to kernel milk stage, when plants are mainly damaged by sucking phytophages (larvae and adults of wheat thrips, aphids). During this period an important element of yield structure – grain weight – in case of damage develops as feeble, deformed, marked by significant underharvest, which could be observed in wheat crops of varieties with mass development of these species.

DISCUSSION

Analysis of phytomonitoring showed that wheat thrips (*Haplothris tritici*) dominated in all studied fields with spring wheat. The vegetation period of 2021 witnessed high air temperatures in spring and summer: in May maximum air temperature reached 35–38°C; the rainfall was absent; the number of days with relative humidity below 30% was 7–9 days; all this indicates that May was arid. In June, the maximum air temperature was 34–36°C, rainfall was recorded only in the second half of June, thus, due to lack of moisture, plant turgor and resistance to damage decreased, which contributed to active reproduction and development of thrips in wheat crops.

Determining the correlation between air temperature during vegetation and numbers of plant feeders showed that the values of coefficients are rather high. This indicates a very strong direct relationship between these indicators, for example, for Zhelezin District correlation coefficient is $r = 0.93 \pm 0.25$, for Uspen District $r = 0.85 \pm 0.30$, and for Ertis District $r = 0.87 \pm 0.35$, respectively, that is, increasing temperature contributes to increasing the number of pests, as seen in the example of wheat thrips. Determining the correlation factor between rainfall and plant-feeding species numbers showed that there is a strong inverse connection between these indicators, so on Zhelezin District $r = -0.76 \pm 0.45$, on Uspen District $r = -0.85 \pm 0.30$, on Ertis District moderate correlation $r = -0.76 \pm 0.30$, that is, lack of moisture leads to increase of plant feeders' amount and vice versa. These correlations are statistically significant ($p < 0.05$), as the significance criteria of correlation coefficients exceed the values of the Student *t*-criterion.

However, Ivantsova [2007], describing the conditions of the Lower Volga Region, argues that dry hot weather in summer contributes to increase of wheat thrips number in the current year, but accelerated development of wheat reduces the duration of larval feeding and dooms them to considerable death in winter; therefore, their number decreases in the next year. Researchers of Saratov Agrarian University found that the number of wheat thrips decreased two-fold with an increase in rainfall to 10–15 mm [Chekmareva, Likhatskaya 2009].

Wheat thrips in wheat crops are phenologically adaptive, i.e., their life cycles are closely related to the crop development stages. The first images of this species may be already observed at the wheat emergence stage (field 16(1)), Zhelezin District, as early as 2–7 adult species per stalk; the highest number of thrips is recorded in the heading stage (field 65, Uspen District, 10–15 adults per ear). This stage is the most suitable for the reproduction of the species. Adult species accumulate at the leaf base, feeding on plant sap, and whitish spots appear in the feeding places.

During feeding of the larvae, damaged flowers die off, so the ear develops through grains, resulting in lower yield (weight of damaged grains decreases from 1 to 14%) and lower quality of seeds (laboratory germination rate decreases from 98 to 72%). It was established that their harmfulness is 1.71 mg of yield per year from the feeding of one species [Sagitov, Ismukhambetov 2004]. In addition, plants grown from seeds damaged by the wheat thrips will be more susceptible to abiotic and biotic stress factors, and, consequently, this will reduce their productivity [Zhichkina 2014].

Damage of wheat plants in the initial stages of development by grain flea beetles (*Phyllotreta vittula*) was also observed, especially in field No. 31 of Ertis District, which is associated with the early sowing of wheat (May 5). The most dangerous is the grain flea beetles in years with early spring droughts, which was typical for the vegetation period of 2021.

Timoshenkova [2018], exploring the steppe conditions of the Orenburg region, found out that the weather conditions determine the prevalence and harmfulness of the flea beetles at the sprouting and tillering stages. Low-temperature background contributed to a decrease in the prevalence of the flea almost twice compared with the years with hotter weather during this period.

Aphids become more harmful in dry years since plants lose turgor and resist damage due to the lack of moisture. Weather conditions of the vegetation year 2021 contributed to increasing of aphids' numbers in July–August; the growth was especially marked from the earing stage to the full-ripe stage in the Uspen District. During this period the aphids fed on underdeveloped plants. The wheat aphid (*Schizaphis graminum*), feeding on the lower leaves of wheat, injects poisonous saliva into the feeding site, thus reducing the number of productive shoots. Our data are consistent with the studies of other scientists indicating that drought aggravates the degree of infestation and plants affected by aphids die at high temperatures [Kindler 2002].

Evaluation of the biometric indicators of the crop and crop condition showed that plants in the phase of full grain ripeness of the 'Triso' wheat variety in both Uspen District (field 65, Lozovskoye) and Ertis District (field 31) were stunted, the ear is small, the grain is small. In contrast, the other varieties had better indicators on the biometry of plants and grain weight.

We believe that this is more related to the timing of sowing the culture, as 'Triso' variety was sown earlier while there is enough moisture in the soil after snowmelt, as in our region is the main limiting factor (April 28 and May 5). However, May was characterised by higher air temperatures and lack of rainfall, which led to slow growth of the crop, poor bushiness, and formation of a weak secondary root system, which subsequently affected the productivity of wheat.

'Triso' variety is also marked by slow development after the emergence of seedlings, reduced assimilation properties of the root system, thinning of seedlings with lack of moisture in the upper soil layer, the possibility of severe damage by Oscinella fly, wireworms, and flea beetles. All these factors could also contribute to the reduction of crop productivity in adverse conditions of the growing season.

'Triso' variety is quite promising for our region, allowing to start sowing early, but high temperatures and lack of moisture during tillering crops do not allow it to realise its full potential, so when cultivating this variety must be more carefully selected timing of sowing in accordance with the climatic characteristics of the region.

There are recommendations for different districts of the Pavlodar region in the terms of sowing spring wheat, which increases the potential productivity and reduces damage from plant-feeding species. The remaining wheat varieties were sown from 15 to 24 May in the optimal conditions, recommended by scientific institutions. Thereby, the most vulnerable stages got under the summer maximum of rainfall, typical for the third decade of June in the North-East of Kazakhstan, which allowed the crop to develop normally.

'Likomero' variety is characterised by the rapid development of plants in the initial stages of growth, a large number of seedpods, and the mass of thousands of seeds, well tolerates early spring frosts, but may be affected by fungal diseases. In the conditions of the region with a lack of moisture in the soil, the important point in growing this variety is the timely implementation of fieldwork aimed at the accumulation and rational use of soil moisture.

In the conditions of Zhelezin District plants variety 'Uralosibirskaya' (field No. 57) formed a good stem and optimal parameters of grain quality, probably due to the high adaptive capacity of the variety to adverse weather conditions of the region. The crops of this variety were damaged by a higher number of grain pests, namely wheat thrips and wheat flies (*Fhorbia fumigate*, *Chlorops pumilionis*). It may be explained by the fact that the wheat was sown directly on the stubble background of wheat last year. Due to the wintering of these species in the root and plant residues of plants, in this growing year, there was an increase in them on this preceding crop, compared with the preceding crop (complete fallow in field number 16(1) in Zhelezin District).

Thus, the opposite picture is observed in the Uspen District: in the field No. 65 (Kovalevsky) in crops of 'Omskaya 35' wheat with the complete fallow preceding crop more intense invasion of plant-feeding species is noted, although there are few crop residues and straw on the field, besides, the last main tillage in the pair is done at greater depth, which worsens conditions of wintering for thrips than in the field No. 65 (Lozovskoye), where insects can overwinter in straw and stubble additionally. The reason is the crops form in connection with the favourable conditions created by the preceding complete fallow crop, a large aboveground mass and more attractive to insects.

'Kazakhstan 15' variety is brought out by local breeders and well adapted to the adverse soil and climatic conditions of the region, which allows for optimal sowing time to get a good harvest of high-quality grain. In general, for the preceding flax significant excess of plant-feeding species of grain by stage of crop development was not observed (field No. 50, Ertis District).

The use of a mixture of varieties instead of one variety as a method of controlling insects, such as aphids, is recommended by a number of scientists, as they note a decrease in the number of pests and an increase in crop yield [DUAN 2022; GRETTENBERGER, TOOKER 2017].

CONCLUSIONS

Thus, a comparative analysis of different wheat varieties, sowing dates, and preceding crops showed that all this has a great influence on the species composition and several pests.

In addition, climatic conditions of the growing season 2021 largely determined the predominance of those pest species that found the dry conditions favourable in terms of reproduction and feeding.

Intensive development of agriculture, implying the use of new technological schemes of growing wheat, sowing of varieties of foreign selection, previously not cultivated in local conditions, climate change contribute to the implementation of active processes in agrocenoses to form new food relations. Thus, the relevance of the evaluation of plant feeders taking into account ecological approaches and techniques used increases. Knowledge of the mechanisms of population dynamics and features of the species composition of wheat pests, their relationships with the crop, the complex influence of agrotechnological methods on them create conditions for creating a scientifically based system of wheat protection and the development of effective forecasts of plant feeders' reproduction.

Rational use of agronomic techniques (sowing date, preceding crop, variety) with regard to the biological characteristics of the crop and the periods of coming out of wintering, feeding and development of insect pests can reduce the degree of phytophage damage to the plant without reducing its productivity. Rejection of chemical means of protection also has a beneficial effect on the development of entomophages in wheat crops.

Since there is no information on the phytosanitary situation in wheat agrocenoses of the North-East of Kazakhstan, the data obtained contribute significantly to the study of insect complexes inhabiting the crops and provide comparative material for similar studies in other regions.

Ample information on the main plant-feeding species in the conditions of the region and the potential harm at vulnerable stages of wheat vegetation may help to organise protective measures purposefully, taking into account the number of species, as well as apply more efficient agricultural techniques to reduce the number of plant feeders during the most dangerous periods of crop development.

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