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Use of Intermediate Crops to Increase Productivity of Irrigated Arable Land in Southeastern Kazakhstan

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ABSTRACT

The results of the study open up fundamentally new areas of intensive use of irrigated land in the southern and south-eastern Kazakhstan, ensuring harvest of two crops per year. For the first time, a technology for creating a green conveyor based on the bioclimatic potential of the growing area has been developed. By taking into account agro-climatic conditions we determined climatic requirements of plants suitable for harvesting two crops per year. The aim of the research was to increase productivity of irrigated land, by using intermediate crops to produce two harvests per year and to create a green conveyor to provide the livestock industry with highly nutritious green fodder. The research was carried out at the experimental and production station of the research, production, and educational center of Bayserke-Agro LLP of the Talgar district of the Almaty region, on light chestnut soils. The main crops, winter rapeseed and triticale, grew since early spring. In the phase of full flowering, rapeseed accumulated 6,760 g of green biomass per m^2, and in the phase of grain setting, winter triticale accumulated 6,480 g of green biomass per m^2. In the rapeseed flowering phase, the yield of green biomass reached 676 centners per hectare, and that of triticale, 648 centners per hectare. The yield of the ripe rapeseed grain was 25.2 centners per hectare, and that of triticale, 63.8 centners per hectare. The intermediate crop, corn for grain, can complete its vegetation after harvesting rapeseed and triticale for green biomass. An additional grain crop amounts to 73.0 centners per hectare, and an additional green biomass yield for silage, to 720 centners per hectare. By sowing intermediate crops, it is possible to harvest larger amounts of fodder from irrigated arable land. In the option without intermediate crops, the total harvest of feed units was 67.9 centners per hectare, and in the option with sowing corn as an intermediate crop for silage and grain. The results showed that the highest net income of 143.8–160.8 thousand tenge per hectare and the profitability level of 89.8–97.5% were obtained when sowing intermediate crops after harvesting winter rapeseed and triticale.

Keywords: intermediate crops, intensive use of land, irrigation, rapeseed, triticale, corn.

INTRODUCTION

Today, the main aspects of the use of irrigated land show the relevance of research aimed at increasing the efficiency of arable areas by growing additional species of intermediate crops [Lentochkin et al., 2013]. Intermediate crops are an important source of high-quality organic green fertilizers [Kishev et al., 2023]. Intermediate crops prevent salinization and leaching of nutrients from the arable layer; they are also an important means of combating soil erosion. They are of great phytosanitary importance in crop rotation, as they weaken harmful plant pathogens and reduce weed contamination of crops [Kadyrov and Fedotov, 2019]. Intermediate crops play a special role in specialized agriculture, by reducing the entirety of the main crops grown. Being different from the main crops in biology and cultivation technology, they play a role of the lost elements of crop rotation [Barotov, 2023]. When creating a crop rotation for two crops on irrigated lands, intermediate crops have a greater opportunity to achieve maximum genetically determined productivity, since they will suffer less from weather fluctuations. Therefore, even in conditions of controlled moisture supply their yield is more stable and reliable [Kovalenko, 2016].

Sufficient and sustainable production of agricultural yields is interconnected with the conditions for preserving and improving soil fertility, and with the efficient use of irrigated lands. On irrigated lands, the yield of agricultural crops and total productivity her hectare are three to five times higher than on rain-fed lands [Minhas et al., 2020]. Irrigation is a powerful factor of intensification of agricultural production. Globally, irrigated lands occupy about 19% of arable land while producing almost half of all agricultural crop. In the United States, 18% of the area of agricultural land is irrigated, but it accounts for 40% of agricultural production [Ukhov and Lentochkin, 2020; Samimi et al., 2020]. Currently, the Kazakh agriculture is unthinkable without innovative water-saving technologies. Therefore, it is necessary to reduce the area of crops with high water consumption and transfer 15% of the area of irrigated crops to water-saving management [Barrett et al., 2017]. The use of waste water for irrigation definitely has its advantages, because it provides vital nutrients and organic substances, reduces water and mineral fertilizer consumption, and reduces pollution of water resources [Komarova and Slabunova, 2021]. Agriculture in Kazakhstan largely depends on weather conditions and is at greater risk of crop failure in dry years due to moisture shortages. The availability of irrigation is particularly important for southern regions with frequent droughts and large variations in yield and gross yield [Thevs et al., 2017]. To increase the efficiency of irrigation and profitability of crop cultivation, it is necessary to take into account a number of factors, such as climate, terrain, soil properties, crop response to irrigation, water table, the method of irrigation, etc., as well as the availability of a market for agricultural products [Zinzani, 2015].

Novel technologies make it possible to ensure high yields, since an important aspect of irrigated agriculture is the choice of the irrigation method: the main reason for the destruction of soil structure when exposed to water is a blast wave of air trapped in micro-aggregates and displaced from soil [Hamidov and Helming, 2020]. Modern methods of irrigation (drip, intra-soil), as well as sprinkling and irrigation along furrows-slots are less destructive [Li et al., 2019]. In these cases, the air is released more slowly and the soil structure is better preserved, while the dispersion coefficient decreases [Harmanny and Malek, 2019].

To further increase the irrigated arable land productivity in Kazakhstan, it is necessary to introduce water-saving innovative technologies that will contribute to the efficient use of irrigated land, which is an urgent problem today [Atakulov et al., 2017].

The increase in agricultural production can be achieved by increasing the yield of agricultural crops. One of the important reserves for increasing crop yields is irrigated land [Atakulov et al., 2020]. To increase irrigated land productivity, intensive use of irrigated arable land by obtaining two or three crops per year in the same field and increasing irrigated land up to three million hectares by 2030 are of particular importance [Aldazhanova et al., 2022]. Climatic resources are one of the main natural factors that determine conditions for agricultural development. The development of agriculture requires a rational geographic distribution of its industries based on careful consideration of agro-climatic resources. By taking into account agro-climatic conditions, it is possible to assess climatic suitablility of a particular territory to the requirements of agricultural crops [Zhildikbaeva et al., 2019; Yerseitova et al., 2018].

Cultivation of two or three crops per year by sowing intermediate crops is aimed not only at obtaining additional products, but also at achieving a positive agrotechnical effect. Intermediate crops enrich soil with fresh organic matter, prevent salinization and leaching of nitrates and other important compounds into deep subsurface horizons, and improve the water-physical properties of soil [Ergashev et al., 2020; Umurzakov et al., 2020].

Agro-climatic conditions of the southern and south-eastern regions of Kazakhstan where irrigated agriculture is well developed enable an effective use of irrigated land during the entire growing season. However, in practice, farmers do not use these opportunities. Thus, after harvesting spring and winter wheat, there is enough time (90-120 days) to cultivate intermediate crops [Taner et al., 2015].

Research studies carried out in Kazakhstan demonstrated that cultivation of two crops per year in the same area with a correct selection of the main (first) and intermediate (second) crops has not led to a decrease in soil fertility, while allowing for intensive use of irrigated arable land [Ospanbaev et al., 2009; Alkenov et al., 2012].

By now, the fertile layer of irrigated serozem soils has decreased by 30%. Humus content in the soil decreased, therefore the fertile soil layer is depleted. Therefore, the development and implementation of ways to obtain two crops per year by sowing intermediate crops and of water-saving technologies (e.g. drip irrigation) is a priority for agricultural development. Drip irrigation helps to reduce the irrigation rate by 40–50%, prevents salinization and irrigation erosion, and ensures rational use of mineral fertilizers [Al-Ghobari and Dewidar, 2018; Ospanbayev et al., 2017].

Today, one of the main challenges of irrigated farming is the development of an optimal combination of the main crop-forming factors and, above all, selection of crops, soil cultivation system, and irrigation and nutrition regimes [Quandt et al., 2023]. The choice of crops is also important in irrigation, since cultivated plants respond differently to irrigation. The most responsive crops include alfalfa, corn, winter wheat, sugar beet, and fodder root crops, while oats, spring barley, buckwheat, and annual grasses respond poorly to irrigation [Nilahyane et al., 2018]. Thus, irrigation makes it possible not only to increase yields (by reducing the dependence of agriculture on droughts), provide livestock with high-quality feed, and the population of the region with fruits, grapes, vegetables and potatoes, but also to sell surplus products to other regions, i.e. to reduce import dependence and improve food security. All these issues have been studied in the research, production, and educational center of Bayserke-Agro LLP since 2021. Intermediate crops were sown in the field after the main crop harvest in the same year in order to obtain an additional harvest. In the conditions of the Almaty region, most crops occupy 50-70% of the area during the warm period of the year. After harvesting spring and winter crops, the fields remain empty for two to three months. During this period, 100–150 mm of precipitation falls, and the sum of active temperatures reaches 980 °C or 30–35% of agro-climatic resources of the warm season. The number of frost-free days can be up to 60–65. This is enough to get an additional harvest of stems, crops or manure used as green feed or green fertilizer. With late spring sowing, there may be enough time to get an additional harvest of winter green biomass. The purpose of our research was to obtain scientific evidence for the alternation of adapted crops to increase productivity of irrigated arable land and soil fertility.

MATERIALS AND METHODS

The climate of the south and south-eastern agricultural areas of Kazakhstan is warm temperate continental, and the soils are light chestnut. The study area was located in the southern part of Kazakhstan, in the Almaty region. The average annual temperature was 23 °C, and the annual frost-free period was 165 to 170 days. Annual precipitation was 600–650 mm, with 50–75% of precipitation falling in summer (from April to October). Based on the crops selected, yield data, fodder units harvested, and the approximate timing of sowing and harvesting, a green conveyor was designed, which is recommended only for the conditions of the south-east of Kazakhstan. The average annual temperature was 23.2 °C, and the average annual precipitation, 628 mm. Given the high feed value of winter rapeseed and triticale, they were selected as the main crops for this study, and can also be recommended for the creation of an effective green conveyor for the regional soil and climatic conditions. Other forage crops are available; however, they are less valuable in terms of feed value. The field experiment started in May 2021. The predominant local intensive two-season crop cultivation was carried out with annual rotation of winter barley, winter triticale and winter rapeseed. Intermediate crop was corn for grain and silage. Winter triticale was sown after tillage in early October and harvested in late May of 2022. Corn was sown in early June and harvested in early October of each year. Before sowing the next crop, above-ground residues were removed from the soil surface. From the beginning of the experiment in 2021, sampling for chemical analysis was carried out until 2023.

The following main crops were used in the field study to obtain two harvests per year: winter barley, winter triticale and winter rapeseed. As an intermediate crop, corn for grain and silage was used. The following scheme for conducting field experiments was adopted (Table 1). The total area of the experimental plot was 5.0 ha, the size of the sub-plots was 300 m^2, and replication was threefold.

In the framework of the project field experiments and laboratory research were conducted. Field experiments were carried out in the fields

Table 1. Experimental design

Main crop		Intermediate crop
Winter barley (control)		Without intermediate crop
Winter triticale for	grain	Corn for silage
	green biomass	Corn for grain
Winter rapeseed for	grain	Corn for silage
	green biomass	Corn for grain

of the experimental and production station of the research, production, and educational center of Bayserke-Agro LLP, in the Almaty region of Kazakhstan. Phenological observations of plant growth and development were carried out according to the method of the State Commission for Variety Testing [Atakulov et al., 2020; Ospanbayev, 2005]. Soil moisture measurements were carried out concurrently with the main phases of development of the main and intermediate crops. Soil moisture content was measured by thermostat-weight method of drying soil samples to constant weight. The sampling was replicated three times [Ospanbayev and Karabayev, 2009]. Field germination of seeds was assessed by counting full seedlings on four permanent plots of 0.3 m^2 each. Plant standing density was assessed by counting the number of plants in 0.3 m^2 plots at the beginning and end of the growing season. The dynamics of plant biomass accumulation was assessed by the measurement of wet and dry mass of samples from each sub-plot concurrently with the main phases of crop development [Ospanbayev, 2005]. Sampling for the nutrient content in soil and plants analysis was carried out concurrently with the main phases of development of the crops studied. The following methods were used in soil studies: total humus content was determined according to the method of I.V. Tyurin modified by V.N. Simakov [Kuziev, 2002]; labile humus, according to the method of I.V. Tyurin modified by V.V. Ponomareva and T.A. Plotnikova [Alkenov et al., 2012]; easily hydrolyzable nitrogen is determined by the method of I.V. Tyurin and N.V. Kononova [Alkenov and Atakulov, 2012]. In irrigated agriculture, timely determination of the conditions and norms of irrigation plays an important role. Irrigation was carried out when soil moisture reached 70% of the lowest moisture capacity [Kostyakov, 1960]. Processing of yield data was carried out according to Dospekhov [Dospekhov, 1985].

The economic efficiency of the methods of crop cultivation was assessed according with adopted costs per unit of production per hectare, adopted methods of performing agrotechnical work, and generally accepted methods.

RESULTS AND DISCUSSION

The results of the research confirmed that the balance of various biological features (cereals, fodder, technical) and cultivation technologies (continuous sowing method, tilled crops), programmed norms of mineral and organo-mineral fertilizers and soil treatment systems is a fundamentally important feature affecting the productivity of arable land and crop yield. At the same time, it was established that yield largely depends on the availability of soil mineral and humus content. Intermediate crops were sown in the field after the harvest of the main crop in the same year in order to obtain an additional yield.

In our field experiments, winter barley without intermediate crop was used as a control (Figure 1). In this case, after harvesting barley intermediate crops were not sown, and the irrigated field was empty until the autumn. Along with winter barley, winter triticale and winter rapeseed were sown as the main crops. Efficient use of irrigated land by sowing intermediate crops increases the amount of fodder units harvested. The total harvest of fodder units amounted to 68.2 centner/ha, and in the variants with intermediate crops, the total weight of fodder units harvested was from 188 to 276.3 centner/ha.

The results of observations of the growth, development and accumulation of the above-ground biomass of the main crops showed that from early spring on, these crops rapidly grew and accumulated the above-ground biomass.

The results of observations of the growth and development of the main crops in the grain setting phase are shown in Table 2.

As can be seen from the data (Table 2), a very high number of stems of winter barley and triticale was observed. The seeding rate of these crops

Figure 1. Winter crops: triticale (left) and rapeseed (right)

Table 2. Growth, development and accumulation of the above-ground mass of the main crops in the grain setting phase in an area of 1m^2, 03.05.2021

Main crop	Average number of plants, pcs/m^2	Average		Weight, g	
		Plant height, cm	Number of stems, pcs.	Raw matter	Dry matter
Barley for grain	32	43	22	4 980	2 505
Rapeseed for green biomass	65	78	-	4 030	1 980
Triticale for green biomass	36	45	23	5 112	2 520

was only 30 kg/ha. The maximum accumulation of the raw and dry matter (5 112 and 2 520 g respectively) was observed in triticale.

In our field experiments, we continued to monitor the growth, development and accumulation of above-ground mass in the flowering and ear formation phases, and estimated growth and development of the main crops (Table 3).

In the flowering phase, rapeseed reached 118 cm in height and accumulated the maximum aboveground biomass: the raw biomass was 6 760 g/m^2, and dry biomass, 3 210 g/m^2. Winter triticale reached 110 cm in height, raw biomass was 6 480 g/m^2, and dry biomass, 3 140 g/m^2.

According to the experimental design, half of the winter triticale and rapeseed crops was left until the grains ripened, and the remaining area of triticale and rapeseed was harvested for green biomass on May 25. Winter barley was left, as a control, until the grains ripened.

The yield of green biomass of winter rapeseed was 676 centners per hectare, and that of triticale, 648 centners per hectare. After harvesting the main crops of triticale and rapeseed for green biomass, corn was sown for grain on May 27.

We conducted a chemical analysis of green biomass of triticale, rapeseed and barley during the ear forming phase in the accredited testing center for the quality of agricultural products at the KazRIED of livestock and fodder production. Both raw and air-dry samples were used for the analyses (Table 4).

The feed unit of green mass of rapeseed was 0.20 kg, and in barley and triticale, 0.22 kg; the

Table 3. Accumulation of the aboveground biomass of the main winter crops in the ear formation and flowering phases in an area of 1m^2, 25.05.2021

Crops	Average number of plants, pcs/m^2	Average		Weight, g		Biological yield, centner/ha
		Plant height, cm	Number of stems, pcs.	raw	dry	
Barley (control)	32	97	23	5 696	2 890	570
Rapeseed	65	118	-	6 760	3 210	676
Triticale	36	110	23	6 480	3 140	648

Table 4. Results of the chemical analysis of filed samples

Sample	Feed unit, kg	Digestible protein, g	OE MZD	ECE
Rapeseed	0.20	39.99	2.33	0.23
Barley	0.22	31.33	2.37	0.24
Triticale	0.22	34.80	2.39	0.24

highest amount of digestible protein accumulated in rapeseed, 39.99 g (Table 4).

In our study, intermediate crops of corn for grain and silage were sown at two separate time points. For the first time, after harvesting winter rapeseed and triticale for green biomass, and for the second time, after harvesting rapeseed and triticale for grain. On the day following the sowing of the intermediate crop, watering was carried out at a low rate, by the drip method (Figures 2, 3).

Corn was sown for grain on May 27, 2021, after harvesting winter rapeseed and triticale for green biomass, and for silage, on July 8, 2021, after harvesting winter rapeseed and triticale for grain.

Corn seedlings appeared after 5-6 days. With an increase in average daily temperatures and with optimal soil moisture, they actively grew, developed and accumulated biomass. The results of observations of the growth and biomass accumulation of the intermediate crop are shown in Table 5.

During the growing season, the onset of the individual phases of development of the intermediate crop was observed. The timing of irrigation and irrigation norms were determined, and at a soil moisture content of 70% of the lowest moisture capacity irrigation was carried out by drip method.

Figure 2. Watering

Figure 3. Sowing of intermediate crop

Table 5. Growth and accumulation of biomass of the intermediate crop in an area of 1 m^2, 03.08.2021

Intermediate crop	Sowing date	Raw weight, g	Average number of plants, pcs.	Average height of plants, cm	Dry mass, g
Corn for grain	27.05	7020	10	230	3 600
Corn for silage	08.07	740	14	50	360

Table 6. Intermediate crop yields, average for 2020-2021

Main crop	Intermediate crop	Date	Average plant height, cm	Crop yield, centner/ha	
				grain	green biomass
Winter rapeseed and triticale for green biomass	Corn for grain	13.09	265	73	-
Winter rapeseed and triticale for grain	Corn for silage	20.09	210	-	720

Figure 4. Measuring corn height

The results obtained show the advantages of re-sowing crops after the main ones. Intermediate corn crop sown after the harvest of the main rapeseed crop and cultivated for grain and silage, grew intensively, developed and produced high yields of silage and grain (Table 6, Figure 4).

Based on the data given in Tables 3 and 6, we provide the totals of crop yields (Table 7). Table 7 shows that after harvesting winter rapeseed and triticale, the intermediate crop (corn) reached its maximum ripeness and yielded 73.0 centner/ha of grain. After harvesting corn for grain, there was a sufficient number of days left for soil cultivation and sowing of winter crops. The largest number of feed units (241 centner/ha) was collected in the variant with winter triticale grown for green biomass and followed by corn for grain an intermediate crop.

We conducted an agroeconomic assessment of the intensive use of irrigated land. The economic analysis showed that for intensive and efficient use of irrigated land during the growing season, it is necessary to make the right choice of main and intermediate crops and get two yields in one year from the same area (Table 8).

Thus, based on economic calculations, it was established that with intensive use of irrigated land by sowing intermediate crops, it is possible to achieve a net income of 159–160.8 thousand tenge/ha with a profitability of 97.0–97.5%.

In barley, the strongest correlation (0.99) was found between plant height and yield, and a similarly high correlation (0.98), between plant height and feed units (Fig. 5). In rapeseed grown for green biomass, the strongest correlations were found between plant height and yield (0.91) and plant height and feed units (0.97); there was also a relatively strong correlation (0.81) between raw and dry biomass (Fig. 6). In rapeseed grown for grain, all correlations were weaker than in rapeseed grown for biomass, and there were also negative correlations between dry biomass and plant height, yield and feed units (Fig. 7). The strongest positive correlation (0.86) was between the weight of 1000 seeds

Table 7. Yields of the main and intermediate crops, and fodder units, centner/ha, average data for 2020-2021

Main crop		Yield	Feed units	Intermediate crop	Yield of green biomass	Feed unit	Total feed units
Winter barley (control)		57.6	69.7	-	-	-	69.7
Winter rapeseed	grain	25.2	40	Corn for silage	720	158.4	198.4
	green biomass	676	138	Corn for grain	73.0	98.0	236
Winter triticale	grain	63.8	76	Corn for silage	720	158.4	234
	green biomass	648	142.6	Corn for grain	73.0	98.0	241

Table 8. Agroeconomic assessment of the intensive use of irrigated land, average for 2020-2021

Main crop		Average crop yield, centner / ha	Intermediate crop	Average yield centner/ha	Gross output, thousand tenge/ha	Total costs, thousand tenge/ha	Conditional net income, thousand tenge/ha	Profitability level, %
Winter barley (control)		57.6	-	-	201.6	135	66.6	49.3
Winter rapeseed	grain	25.2	Corn for silage	720	303.8	160	143.8	89.8
	green biomass	676	Corn for grain	73.0	325.8	165	160.8	97.5
Winter triticale	grain	63.8	Corn for silage	720	252.1	160	92.1	58
	green biomass	348	Corn for grain	73.0	324.4	165	159.4	97.0

and feed units. When triticale grown for green biomass was considered (Fig. 8), the strongest correlation was found between plant height and feed units (0.98) and plant height and yield (0.96). There were several negative correlations between raw biomass and other characteristics of triticale. In triticale grown for grain, very strong positive correlations were found between plant height and the weight of 1000 seeds, yield, and feed units (Fig. 9). The weight of 1000 seeds was also strongly correlated with yield and feed units. Dry biomass was negatively correlated with all other characteristics, but one (raw biomass). In corn grown for green biomass, the strongest correlations were found between plant height and yield, and plant height and feed units (Fig. 10). In corn grown for grain (Fig. 11), there were strong correlations between plant height and all other characteristics except for yield.

Overall, in crops grown for green biomass, the strongest correlations were found between plant height and yield, and plant height and feed units. In crops grown for grain, the strengths of the correlations was less uniform and more dependent on a type of crop in question.

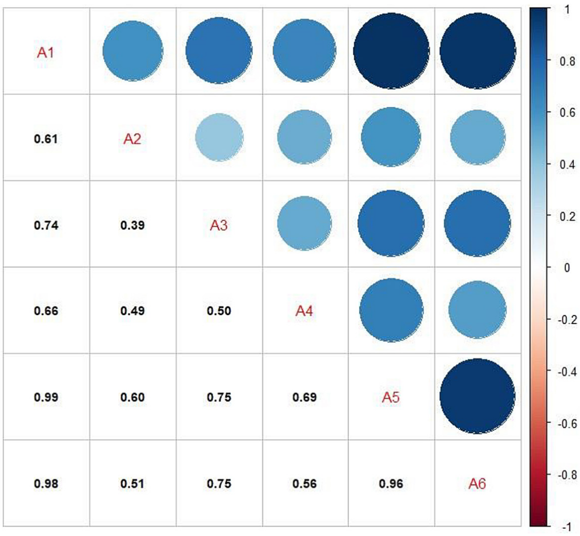

Figure 5. Pairwise correlations between plant height, cm (A1), raw biomass, g (A2), dry biomass, g (A3), the weight of 1000 seeds, g (A4), yield, centner/ha (A5), and feed units (A6) in barley

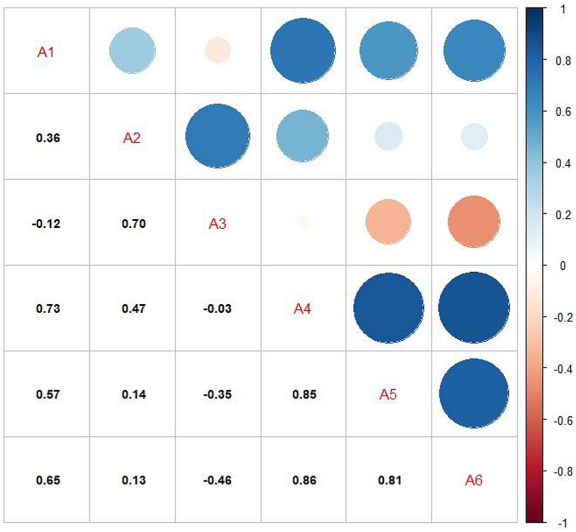

Figure 7. Pairwise correlations between plant height, cm (A1), raw biomass, g (A2), dry biomass, g (A3), the weight of 1000 seeds, g (A4), yield, centner/ha (A5), and feed units (A6) in rapeseed grown for grain

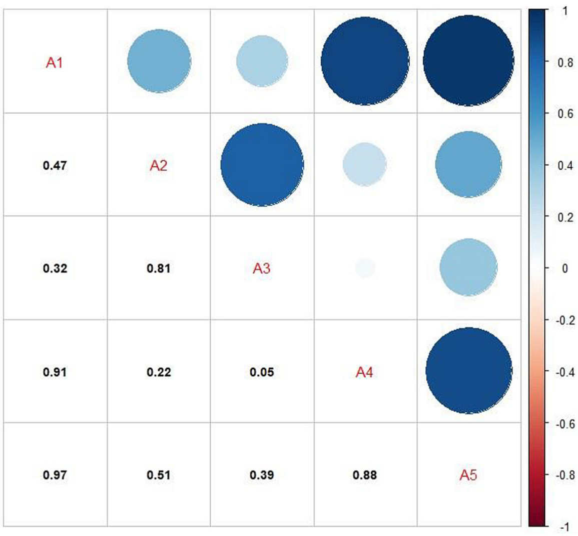

Figure 6. Pairwise correlations between plant height, cm (A1), raw biomass, g (A2), dry biomass, g (A3), yield, centner/ha (A4), and feed units (A5) in rapeseed grown for green biomass

Figure 8. Pairwise correlations between plant height, cm (A1), raw biomass, g (A2), dry biomass, g (A3), yield, centner/ha (A4), and feed units (A5) in triticale grown for green biomass

Our study demonstrates feasibility of a full-scale scientific project on a permanent basis of the best varieties for intermediate crop growing and the use of integrated mechanization ensuring the optimal soil moisture regime and combining a water-soil resource into a single unit. This approach gives an undeniable impetus to increase the effective productivity of the agro-industrial complex. The size of the harvest and its quality largely depend on the availability of elements of mineral nutrition in the soil. To determine the initial state of the mineral nutrition elements in the soil, soil samples were taken from the study site. Before the experiments were carried out, the main agrochemical characteristics of light-dark-chestnut soils were estimated in the arable layer (0–30 cm). The humus content was 2.58–2.44%; total nitrogen, 0.122–0.062%; phosphorus, 0.19–0.17%; and potassium, 1.19–2.1%; the mobile phosphorus content was in the range of 20–25 mg/kg, i.e. this soil has a relatively low content of mobile phosphorus. When the experiments were completed, the following fertilization recommendations were made: 200 kg/ha of 15-15-15 NPK should be spread before ploughing, and 100 kg/ha 15-15-15 NPK, during sowing; a foliage fertilizer should be used in the tillering phase, either phosphorus-containing fertilizer Kontrolphyt PK, 1 l/ha or Plantafol 10-54-10, 2 kg/ha.

Figure 9. Pairwise correlations between plant height, cm (A1), raw biomass, g (A2), dry biomass, g (A3), the weight of 1000 seeds, g (A4), yield, centner/ha (A5), and feed units (A6) in triticale grown for grain

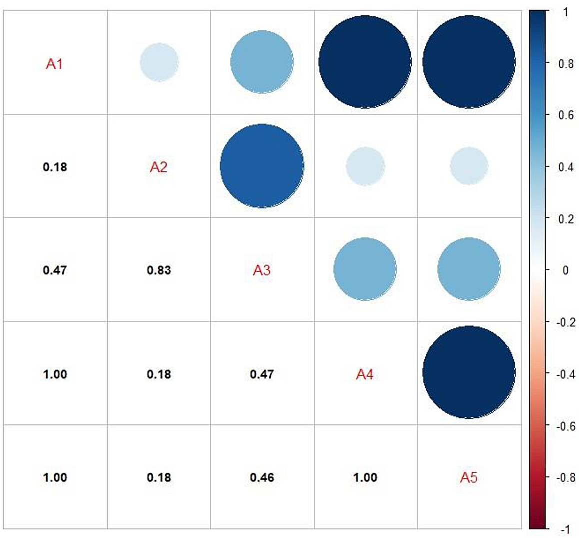

Figure 10. Pairwise correlations between plant height, cm (A1), raw biomass, g (A2), dry biomass, g (A3), yield, centner/ha (A4), and feed units (A5) in corn grown for green biomass

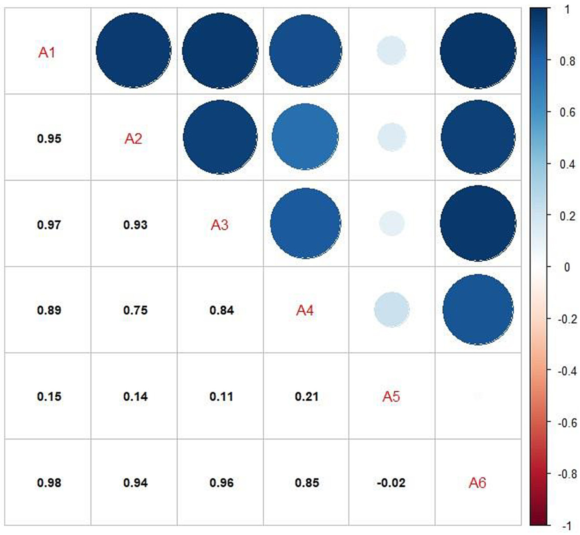

Figure 11. Pairwise correlations between plant height, cm (A1), raw biomass, g (A2), dry biomass, g (A3), the weight of 1000 seeds, g (A4), yield, centner/ha (A5), and feed units (A6) in corn grown for grain

Therefore, a study of the dynamics of nutrients and their balance plays an important role in forecasting productivity of crops, in the development of an irrigated land system and selection of intermediate crops. At the same time, irrigation not only contributes to an increase in the yield of cultivated crops, but, equally important, reduces dependence on weather conditions ensuring stable and guaranteed yields, expand the distribution ranges of agricultural crops, and reduce the share of unsuitable and marginally suitable lands.

Studies conducted in the South-East of Kazakhstan have shown that in the conditions of hillock farming in the Almaty region, precipitation of the first half of summer is effectively used in cultivation of winter crops (barley and triticale), while for the cultivation of the late summer crops (corn) precipitation of the second half of summer is more important. Thus, increased stability of agricultural production and soil resistance to adverse environmental effects is achieved [Panasiewicz et al., 2020; Szempliński et al., 2021]. In the southeast of Kazakhstan, winter triticale and barley crops fit well into crop rotations of various irrigated agricultural landscapes as intermediate crops, which also contributes to improving soil fertility; in particular, crop rotation reduces clogging and weed contamination, and increases the amount of root and crop residues [Kurmanbayeva et al., 2023]. So far, not all aspects of agro-ecological assessment have been sufficiently developed, especially those concerned with soil properties, due to difficulty of formalization. Some of the criteria for this assessment are descriptive in nature and are based on practical experience of in-depth experimental studies, which justifies further development of relevant scientific research [Popova et al., 2023]. The most important landscape features that determine their functioning are relief, lithology, climate, the influence of groundwater, vegetation, and soil cover [Zhapayev et al., 2023]. Agro-ecological assessment is the main subject of landscape analysis, which is carried out in relation to each elementary area of the agro-landscape as an elementary structural unit of the agro-landscape and the basis for the development of an adaptive landscape system of agriculture [Gong et al. 2021].

From the point of view of agricultural use, agro-landscapes are geosystems distinguished by a set of the main agro-ecological factors (determining the use of certain farming systems), the functioning of which occurs within a single chain of energy and mass transfer [Kurmanbayeva et al., 2023]. In other words, an agro-landscape corresponds to an agro-ecological group of lands, in relation to which an adaptive-landscape farming system is being developed. It is a means of managing agro-landscape regimes, ensuring environmental sustainability, biodiversity, and environmental restoration.

In the course of the project, the data were obtained on hydrothermal conditions in the southeast of Kazakhstan, calculations of the crop requirements for the sum of active and effective temperatures, and the correct selection of crops were made, as well as a green conveyor developed, which allows farmers to obtain two crops per year, thereby effectively using irrigated land.

CONCLUSIONS

Based on the results of research aimed to increase irrigated arable land productivity, the following conclusions were drawn:

1. Winter rapeseed and triticale grown as the main crops intensively grew and developed from early spring on, and in the phase of full flowering (25.05) rapeseed accumulated 6760 g of green mass per m^2, and triticale, 6480 g/m^2. In this phase, the yield of rapeseed green biomass reached 676 centner/ha, and triticale, 648 centner/ha. When the growing cycle was completed, the grain yield of rapeseed was 25.2 centner/ha, and the yield of winter triticale was 63.8 centner/ha;
2. After harvesting winter rapeseed and triticale for green biomass, the intermediate crop, corn for grain undergoes full vegetation, and additional grain products can be obtained in amount 73.0 centner/ha. The intermediate crop, corn for silage sown after the harvest of winter rapeseed and triticale, gave 720 centner/ha of additional products in the form of silage.
3. By sowing intermediate crops, it is possible to harvest larger amounts of fodder from irrigated arable land. In the option without intermediate crops, the total harvest of feed units was 67.9 centner/ha, and in the option with sowing corn as an intermediate crop for silage and grain, the total harvest of feed units ranged from 198.4 to 236.0 centner/ha.

The results showed that the highest net income of 143.8–160.8 thousand tenge per hectare and the profitability level of 89.8–97.5% were obtained when sowing intermediate crops after harvesting winter rapeseed and triticale.

The problem of maintaining soil fertility and arable land productivity can be solved by cultivating intermediate crops (up to 133%), which largely contribute to the preservation of productive longevity of soils with humus deficiency. According to our results, the soil of the experimental site under the cultivated crops had the volumetric mass value from 1.22 to 1.24 g/cm^3; the specific mass was 2.54–2.58 g/cm^3; the total porosity, 51.7–54.8%; and the water resistance of soil aggregates, in the range of 37.1–38.9%. The lowest soil moisture capacity averaged 24.5%. These data on agro- and water-physical properties of the soil show that the conditions for cultivation of crops and field experiments were satisfactory. According to the methods used in the study, experiments on soils with humus deficiency were not carried out.

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