Research Article

Effect of Fertilizer Rates on Structural Parameters, Yield and Quality of Intercropping Plants: A Case Study for Azerbaijan

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Abstract | The main purpose of this study was to investigate the effect of fertilizer norms in mixed cropping on the structural indicators, productivity and quality of mixed cropping crops. Intercropping is of great importance in meeting the feed needs of livestock and protecting soil fertility. Thus, the correct and timely application of organic and mineral fertilizers within the normal limit had a positive effect on the growth and development of plants sown in intercrops. The height of the mixed sowing sorghum plant increased to 245-255 cm, and the height of the pea plant increased to 100-110 cm in the variant with 10 t/ha+$N_{70}P_{125}K_{90}$ of mineral and organic-mineral fertilizers. The researches prove that in the variant applied with organic-mineral fertilizers at the rate of 10 t/ha+$N_{70}P_{125}K_{90}$, along with the growth and development of plants, green mass yield has increased significantly. Thus, 62,400 kg/ha of green mass was obtained in the version with manure 10 t/ha+$N_{70}P_{125}K_{90}$ fertilizer, which was 26,300 kg/ha or 72.85% increase compared to the control option without fertilizer. The effect of fertilizer treatments on quality indicators of fodder obtained from mixed sowing was studied. It was found that the amount of crude protein, absolute dry matter, yield of feed unit, amount of digestible protein in the green mass product increased significantly. The most important criterion in terms of quality in forage plants is the crude protein content in the dry matter. There is a positive relationship between nitrogen fertilization and the crude protein content of plants. At the end of the research, we came to the conclusion that in order to obtain a high and quality product from sorghum and pea plants, which are sown mixed in the corner crops, it is more appropriate to apply $N_{90}P_{120}K_{120}$ kg of mineral fertilizers per hectare, and manure of 10 t/ha + $N_{40}P_{95}K_{60}$ of organic and mineral fertilizers.

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Introduction

The world population continues to grow. According to statistics, it is estimated that the population will reach 9.2 billion in 2050. This requires increasing the productivity of agricultural crops and its quality indicators in order to feed the growing population (Maja and Ayano, 2021). In parallel, agricultural products should also be increased.

Studies show that mineral fertilizers and especially nitrogenous fertilizers are of great importance for the increase of productivity of agricultural plants. The intensification of agricultural processes has led to soil depletion (erosion, reduction of organic substances and nutrients), groundwater pollution and other environmental problems (Ludwig *et al*., 2011).

The importance of intercropping is great in preventing soil degradation and restoring soil fertility. Intercropping is an ancient agrotechnical practice practiced worldwide. Cereal-cereal-legume mixtures were considered the most productive form of intercropping because cereals can benefit from the nitrogen fixed in the root nodules of legumes in the current year (Allahverdiev, 2020; Zhang *et al*. 2022).

Corn and soybean crops are widely used as mixed crops around the world. However, practices of mixed planting of sorghum-pea, sorghum-corn, sorghum-sunflower, corn-sunflower and other crops exist in world agriculture. This is due to the coincidence of the vegetation period of the two plants. While corn, the main crop, removes enough nutrients from the soil, the legume soybean plant enriches the soil with nitrogen in the cropping system. Therefore, mixed cropping of corn and soybean plants is a more favorable option for the sustainability of agriculture (Xiao *et al*., 2018; Lee *et al*., 2020; Zhao *et al*., 2020).

In order to reduce the use of mineral fertilizers, it is more convenient to apply organic fertilizers. Along with this productivity, it has a positive effect on the protection of soil fertility. Organic fertilizer provides a number of important elements for plant development and can improve nitrogen use efficiency, plant yield and quality (Lee *et al*., 2019; Yu *et al*., 2020). There are many factors that affect yield, including planting density, tillage practices, tillage practices, site management, and fertilization practices. The use of mineral and organic fertilizers can significantly increase the productivity of plants by changing the level of nutrients in the soil (Zhao *et al*., 2020; Dahal *et al*., 2021; Yang *et al*., 2022).

As a result of intercropping, the field is constantly covered with green vegetation, which prevents degradation to a certain extent, and on the other hand, increases the coefficient of solar energy and soil utilization. However, the correct selection of plants and their types for cultivation during the drought period is also an important condition. Because plants should be planted so that they do not negatively affect soil fertility. In such intermediate crops, the importance of mixed crops is greater in maintaining both the quality of feed and soil fertility. For example, while sorghum, which is one of the cereal crops, absorbs a lot of nutrients from the soil, the pea plant, which is mixed with it, enriches the soil with nitrogen by fixing the free nitrogen in the air through the fur bacteria in its tubers. Thanks to this, not only the green mass product increases, but even its quality increases. It should be noted that, as a result, there is a significant increase in root residues, which has a positive effect on soil fertility (Allahverdiev and Isaeva, 2021; Kiriba *et al*., 2020).

The quality of the product is affected by the genes of plants, as well as external environmental factors and cultivation conditions (Hu *et al*., 1998; Zhang *et al*. 2022). Soybean is widely cultivated in all cropping systems (monoculture or intercropping). It is usually cultivated together with cereals or perennial plants and leads to a significant improvement of soil fertility (Allahverdiev and Aliyeva, 2015; Kiriba *et al*., 2020).

The most important criterion in terms of quality in forage plants is the crude protein content in the dry matter. Green fodder products derived from corn and sorghum are characterized by high energy but relatively low crude protein. However, It is usually cultivated together with cereals or perennial plants and leads to a significant improvement of soil fertility.

In order to meet the needs of food, animal feed and industrial raw materials, productivity and quality in agriculture need to be increased. For this purpose, agricultural lands should be used effectively and soil fertility should be increased. One of the alternatives to increase the productivity and quality of forage crops is the cultivation of cover crops. Thus, arable lands and climate resources can be used efficiently. Determining

the optimum fertilizer rates in the region will increase productivity and quality indicators and will also be useful for preserving the fertility of the soil.

It is possible to produce high efficiency and quality feed in livestock enterprises. Especially green feed has a high nutritional value and it is beneficial to produce it in the enterprise. It is easily consumed by farm animals. Feeds obtained from mixed planting plants are loved by animals due to their taste and smell. Green fodder is rich in dry matter, vitamins, proteins and minerals. It is also claimed that green fodder obtained from mixed products is more economical (Erdogdu *et al*., 2013; Yang *et al*., 2022).

Legumes are the main source of vegetable protein used in the feeding of agricultural animals. Alfalfa is the most common leguminous plant in field forage. Alfalfa is rich in digestible protein, as well as well-prepared protein, vitamin hay meal, hay and haylage compared to other legumes, even legumes. In addition to protein, alfalfa grass and fodder types contain vitamins, digestible carbohydrates, fat, organic-mineral compounds, calcium, phosphorus, potassium, magnesium, sulfur, sodium, etc. There is as the alfalfa plant develops, the amount of nutrients in its content changes significantly (Jafarov and Mehdiyeva, 2014). One of the ways to increase the productivity of plants is the use of mixed products of legumes and cereals in agrocenoses (Xiao *et al*., 2018).

One of the main issues in ensuring sustainability in agricultural production is the balance of organic matter in the soil. Organic matter content is the most important factor affecting the fertility of soils. Organic substances also increase crop yield by making positive contributions to the physical, chemical and biological properties of the soil. Especially nature and environmentally friendly animal and vegetable fertilizer applications contribute to soil fertility by increasing sustainable agricultural production. The main aim of those engaged in agriculture is to obtain the highest return from the unit of fertilizer applied to the soil without harming the environment and to obtain qualified and abundant products. For this reason, it is of great importance and value to apply fertilizers to the soil in the most beneficial way. Therefore, research in this direction can fill the scientific gap and also obtain results that can be a guide for farmers (Beyyavas *et al*., 2022). The main purpose of this study was to investigate the effect of fertilizer treatments in mixed cropping on the structural indicators, productivity and quality of mixed cropping crops. For this purpose, the different effects of different fertilizer treatments on mixed cropping were analyzed in a selected district of Azerbaijan.

Materials and Methods

The experiment was conducted in 2022 and 2023 after harvesting barley from cereal plants in the Uchoglan area of Aghdam district (Figure 1). Aghdam district is located in the west of the country and belongs to the Karabakh Economic Region. Its surface area is 1,150 km^2. Relief of Aghdam district is mainly plain, partly mountainous. Climate is mainly mild-hot, dry-subtropical. Average temperature is between -0,2˚C and 1,8˚C in January, and between 23˚C and 26˚C in July. Annual rainfall is 300-550 mm. According to 2022 data of the the Azerbaijan State Statistics Committee, the total cultivated land in the Aghdam district is 26,307 hectares. Cereals and dried pulses are produced in 38% of this area. In the same year, wheat was produced in an area of 7,793 hectares and barley was produced in an area of 2,134 hectares. Grape and cotton production are also important in the district (ASSC, 2024).

Figure 1: *Aghdam District in Azerbaijan.*

Soil samples were taken from 5 places in the form of an envelope from the researched area and agrochemical analysis was carried out. In soil samples, total humus was determined by I.V. Tyurin, total nitrogen by Keldal, total phosphorus by Lorentz, total potassium by Smith, nitrate nitrogen by Grandval-Lyaju, easily hydrolyzable nitrogen by the method of Tyurin and Ko-nonov, active phosphorus by Machigin, exchangeable potassium by P.V. Protosov, absorbed Ammonia nitrogen was determined by calorimetric

method with Nessler's reagent according to Konev, pH-potentiometric method in water solution (Jafarov and Mehdiyeva, 2014).

After determining the nutrients in the soil, the nutrients that the plants can absorb from the soil are determined. After that, the fertilizer rates were calculated based on the results of the analysis. According to the methodology, dried plant samples are ground in an electric mill and passed through a 1 mm sieve. The roots are crushed, dried and ground. Total nitrogen, phosphorus and potassium are determined in prepared samples.

Total nitrogen, phosphorus and potassium in the plant K.E. Ginzburg, Q.M. Sheglov and E.V. According to Wolff, it was identified in a sediment. Nitrate nitrogen in green mass product A.G. Shestakov, V.P. Determined by the Pleshkov method. Protein was obtained by multiplying total nitrogen content by the conversion factor (soy: 5.71; corn: 6.25) (Bao, 1999).

In the study, sorghum (Stavrapol fodder hybrid) and pea (*Pisum sativum L.*) nail variety were used. For sowing, 30 kg of corn and 30 kg of pea seeds were taken per hectare. During the experiment, organic fertilizer, along with phosphorus, potassium was applied 100% under the plow, and nitrogen was applied in the form of feeding. In the study, the effects of the following fertilizer treatments were analyzed from different aspects. Additionally, comparisons were made with control (no fertilizer) treatments.

$N_{40}P_{60}K_{60}$
$N_{60}P_{90}K_{90}$
$N_{90}P_{120}K_{120}$
$N_{120}P_{150}K_{150}$
Manure 10 t/ha+P_{35}
Manure 10 t/ ha +$N_{10}P_{65}K_{30}$
Manure 10 t/ ha +$N_{40}P_{95}K_{60}$
Manure 10 t/ ha +$N_{70}P_{125}K_{90}$

Results and Discussion

Taking into account the above mentioned, mixed sowing of sorghum and pea seeds was carried out in the gray-grass soils of Uchoglan village of Aghdam district immediately after harvesting of winter barley, after plowing to a depth of 20-22 cm. So, peas were poured into the seed box (bunker) of the seeder, and sorghum seeds were poured into the fertilizer box, and both seeds were sown in the same row.

The effect of mineral and organic-mineral fertilizer rates on the height of sorghum and pea plants, which are mixed with sorghum and pea plants, is measured during phenological observations in different development phases and is listed in Table 1.

As can be seen from the Table 1, when measuring the height of the plants in the milk-wax ripening phase of the sorghum plant, it was determined that the mineral and organic-mineral fertilizer rates had a significant impact on the height of the sorghum and pea plants that were sown mixed in the fields. Thus, the height of the sorghum plant in the no-fertilizer-control option is 152 cm, and the height of the pea plant is 70 cm, while the height of the sorghum plant, which is sown mixed with mineral and organic-mineral fertilizer norms, is 164-245 cm, and the height of the pea plant is 75- It varied between 101 cm.

As a result of phenological observations, it was found that the height of the plants increased in different sizes when the fertilizer rates were changed. Thus, the height of the sorghum plant mixed with $N_{40}P_{60}K_{60}$ fertilizer is 164 cm, and the height of the pea plant is 75 cm, 178 cm when $N_{60}P_{90}K_{90}$ is applied, 87 cm in peas, 210 cm when $N_{90}P_{120}K_{120}$ is applied, respectively. 93 cm, the height of the mixed sorghum plant was 233 cm, and the height of the pea plant was 101 cm.

When organic and mineral fertilizers are applied together, that is, when manure is given at the rate of 10 t/ha+P35, the height of plants is 166 cm, 75 cm, when manure 10 t/ha+$N_{10}P_{65}K_{30}$ is applied, 188 cm, 88 cm, respectively, when manure is given at the rate of 10 t/ha+$N_{40}P_{95}K_{60}$. In the given variant, the height of the sorghum plant was 226 cm, the height of the pea plant was 99 cm, the height of the sorghum plant mixed with manure 10 t/ha + $N_{70}P_{125}K_{90}$ was 245 cm, and the height of the pea plant was 100 cm. As it can be seen, when organic and mineral fertilizers were applied together, they had a better effect on the height of the plants.

As it can be seen, when organic and mineral fertilizers were applied together, they had a better effect on the height of the plants. From the results of phenological observations, it was found that optimal fertilizer rates have a more effective effect on the height and devel-

Table 1: *The effect of fertilizer rates on the height of sorghum and pea plants intercropped in stubble crops.*

Treatments	Height in the milk-wax ripening phase (cm)			
	October, 2022		October, 2023	
	on the background of 3 times irrigation (3,100 m³/ha)			
	sorghum	pea	sorghum	pea
Control	152	70	170	75
$N_{40}P_{60}K_{60}$	164	75	176	51
$N_{60}P_{90}K_{90}$	178	87	191	88
$N_{90}P_{120}K_{120}$	210	93	225	96
$N_{120}P_{150}K_{150}$	233	101	243	108
manure 10 t/ha+P_{35}	166	75	177	83
manure 10 t/ ha +$N_{10}P_{65}K_{30}$	188	88	196	94
manure 10 t/ ha +$N_{40}P_{95}K_{60}$	226	99	250	103
manure 10 t/ ha +$N_{70}P_{125}K_{90}$	245	100	255	110

opment of sorghum and pea plants, which are sown in a mixture, which in turn leads to an increase in green mass yield.

During our research, the effect of fertilizer treatments on the green mass productivity of mixed sowing of sorghum and field peas in corner crops was as shown in Table 2. As can be seen from the table, when 36,100 kg/ha of green mass was obtained in the control variant without fertilizer on the basis of vegetation irrigation 3 times, the productivity increased to 44,900-61,700 kg/ha from the application of different fertilizer rates. Although the highest yield was obtained when $N_{120}P_{150}K_{150}$ fertilizer was applied, mathematical calculations revealed that the highest yield was 61,100 kg/ha when $N_{90}P_{120}K_{120}$ was applied, which is an increase of 25,600 kg/ha or 70.91% compared to the control.

Mathematical calculations performed at the end of the study prove the accuracy of the experiment. E received at the expense of fertilizer is many times higher than the indicator s/ha. Based on the results of the research, we can say that optimal fertilizer rates have been determined for obtaining a high green mass yield during joint sowing of sorghum and peas.

In addition to the productivity of mixed crops (sorghum and pea plants), the influence of optimization of fertilizer norms in the field crops on the quality indicators of the obtained fodder was also studied by us during the research. As a result of the conducted analyses, the amount of crude protein, absolute dry matter, nitrate nitrogen in natural mass, yield per hec

Table 2: *The effect of fertilizer rates and the number of irrigations on the green mass yield of mixed sowing of sorghum and pea in stubble crops.*

Treatments	3 times irrigation (3,100 m³)		
	Average productivity (kg/ha)	Grows	
		kg/ha	%
Control	36,100	-	-
$N_{40}P_{60}K_{60}$	44,900	8,800	24.37
$N_{60}P_{90}K_{90}$	53,700	17,600	48.75
$N_{90}P_{120}K_{120}$	61,100	25,000	69.25
$N_{120}P_{150}K_{150}$	61,700	25,600	70.91
manure 10 t/ha + P_{35}	42,500	6,400	17.72
manure 10 t/ha + $N_{10}P_{65}K_{30}$	51,900	15,800	43.76
manure 10 t/ha + $N_{40}P_{95}K_{60}$	61,800	25,700	71.19
manure 10 t/ha + $N_{70}P_{125}K_{90}$	62,400	26,300	72.85
E = 800 kg/ha P = 2.3%			

Table 3: *The effect of fertilizer rates on the fodder quality of the green mass product obtained from the mixed sowing of sorghum and pea.*

Treatments	Raw protein (%)	Absolute dry matter (%)	Amount of nitrate nitrogen in natural mass (mg/kg)	Per hectare	
				Output of feed unit	Digestible protein (kg)
Control	6.1	21.6	60	7,454	696..6
$N_{40}P_{60}K_{60}$	6.3	23.4	67	9,271	826.2
$N_{60}P_{90}K_{90}$	6.5	24.5	71	11,089	988.3
$N_{90}P_{120}K_{120}$	6.8	25.4	74	12,617	1,124.5
$N_{120}P_{150}K_{150}$	7.1	25.6	82	12,741	1,135.5
manure 10 t/ha+P_{35}	6.2	23.1	67	8,776	782.1
manure 10 t/ha+$N_{10}P_{65}K_{30}$	6.5	24.7	70	10,717	955.1
manure 10 t/ha+$N_{40}P_{95}K_{60}$	6.9	26.5	75	11,791	1,059.9
manure 10 t/ha+$N_{70}P_{125}K_{90}$	7.3	26.8	85	11,977	1,067.4

tare of feed unit and the amount of digestible protein were studied from the quality indicators of the green mass product obtained from mixed crops.

The results of the analyzes are given in Table 3. As can be seen from the table, raw protein was 6.1% in the no-fertilizer-control variant where sorghum and peas were grown mixed with 3 times irrigation (3,100 m^3/ha) in the irrigated fields, while the mineral fertilizer $N_{40}P_{60}K_{60}$ was applied in the norm, while the raw protein was 6.3%, and $N_{60}P_{90}K_{90}$ was given in the norm. 6.5% in the variant, 6.8% when mineral fertilizer $N_{90}P1_{20}K_{120}$ is applied, and 7.1% when $N_{120}P_{150}K_{150}$ is applied.

A similar situation occurred in the options where organic and mineral fertilizers were applied together. Thus, the raw protein is 6.2% in the case of combined organic and mineral fertilizer manure 10 t/ha+P_{35}, manure 10 t/ha+$N_{10}P_{65}K_{30}$ 6.5%, manure 10 t/ha+$N_{40}P_{95}K_{60}$ in the norm 6.9%, while manure 10 t/ha+$N_{70}P_{125}K_{90}$ was 7.3%.

From the results of the analysis, it is known that the amount of dry matter according to the absolute dry weight has increased significantly due to the influence of fertilizer norms. For example; While the amount of dry matter was 21.6% in the control option without fertilizers, it was 23.4% in the option with $N_{40}P_{60}K_{60}$, 24.5% in the option with $N_{60}P_{90}K_{90}$, 25.4% when $N_{90}P_{120}K_{120}$ was applied, and 25.65% when $N_{120}P_{150}K_{150}$ fertilizers were applied. increased to A similar situation occurred in the options where organic and mineral fertilizers were applied together. Thus, raw protein is 23.1% in the variant given manure 10 t/ha+P_{35}, 24.7% when manure 10 t/hec+$N_{10}P_{65}K_{30}$ is given, 26.5% when manure 10 t/ha+$N_{40}P_{95}K_{60}$ is applied in the norm, manure 10 t/ha+$N_{70}P_{125}K_{90}$ was 26.8% in the given option.

In practice, the effect of fertilizers on the amount of nitrates collected in green fodder was determined. The results of the analysis show that mineral and organic mineral fertilizers increase nitrate nitrogen in green fodder. Thus, in the case of the nitrate-free control version, 60 mg/kg of natural mass was collected, in the version with $N_{40}P_{60}K_{60}$ applied, these indicators were 67 mg/kg, in the version given $N_{60}P_{90}K_{90}$, 71 mg/kg, when $N_{90}P_{120}K_{120}$ was applied, 74 mg/kg, when $N_{120}P_{150}K_{150}$ fertilizers were applied, 82 mg/kg. increased to kg.

A similar situation occurred in the options where organic and mineral fertilizers were applied together. Thus, in the case where manure 10 t/hec+P_{35} is given, raw protein is 67 mg/kg, when manure 10 t/hec+$N_{10}P_{65}K_{30}$ is given, 70 mg/kg, when manure 10 t/hec+$N_{40}P_{95}K_{60}$ is applied in the norm, 75 mg/kg, manure 10 t/ hec+$N_{70}P_{125}K_{90}$ was 85mg/kg in the given variant. The results obtained as a result of the analysis were much less than the maximum allowed limit (200 mg/kg in natural mass) in fodder plants. This also proves that the produced product is safe from an environmental point of view. During the research, mineral and organic-mineral fertilizers were studied in terms of feed unit yield and amount of digestible protein in

the green mass product obtained from mixed crops. In the case of the no-fertilizer-control option, the yield of feed units from 1 hectare of land is 7,454, digestible protein is 696.6 kg/ha, while in the $N_{40}P_{60}K_{60}$ applied variant these indicators are 9,271 feed units and 826.2 kg digestible protein, 11,089 feed units in the $N_{60}P_{90}K_{90}$ given variant and 988.3 kg digestible protein, 12,617 feed units when $N_{90}P_{120}K_{120}$ is applied and 1,124.5 kg digestible protein, 12,741 feed units when $N_{120}P_{150}K_{150}$ fertilizers are applied and digestible protein has increased to 1,135.5 kg.

The feed quality indicators were studied and analyzed in the variants of the combined application of organic and mineral fertilizers to sorghum and pea plants grown in mixed crops. Thus, in the variant given manure 10 t/ha+P_{35} 8,776 feed units and 782.1 kg digestible protein, when given manure 10 t/ha+$N_{10}P_{65}K_{30}$: 10,717 feed units and 955.1 kg digestible protein. When manure was applied as a norm 10 t/ha+ $N_{40}P_{95}K_{60}$, there were 11,791 feed units and 1,059.9 kg of digestible protein, and in the variant given manure 10 t/ha+$N_{70}P_{125}K_{90}$, there were 11,977 feed units and 1,067.4 kg of digestible protein, which means a significant increase compared to the control variant without fertilizer.

A study conducted in Northern China indicated that long-term fertilization can effectively improve crop yield, soil fertility, and soil C:N:P stoichiometry. Meanwhile, the single application of an organic fertilizer or the combination of organic and nitrogen fertilizers can improve the condition of nitrogen limitation in arid and semi-arid areas (Liu *et al*., 2021).

In a study conducted in China, corn and soybean were interplanted in 2:2, 2:3 and 2:4 ratios. Two fertilizer levels (normal: 600 kg/ha; reduced: 375 kg/ha) were set. The effects of fertilizer levels and intercropping planting patterns on the growth and yield of intercropping soybeans were studied based on the changes in enzyme activities related to nitrogen metabolism and insect community in the field. The results show that fertilizer reduction significantly reduced the biomass, 100-seed weight and yield of soybean (Li *et al*., 2022).

In a study conducted in India, interaction effect of intercropping system and fertilizer levels were found non-significant for seed quality parameters of chickpea. The experiment consists of four intercropping systems viz., sole chickpea, chickpea + sorghum (4:2), chickpea + safflower (4:2), chickpea + linseed (4:2) and three fertilizer doses includes 100 %, 125 % and 150 % RDF (Gowda *et al*., 2020).

In other study conducted in India, the pooled sorghum equivalent yields among the sorghum + chickpea intercropping systems ranged between 2,640 to 2,950 kg/ha and were significantly superior over sole crops of sorghum (2,210 kg/ha) and chickpea (2,074 kg/ha). Sorghum with chickpea, might have increased light interception in chickpea, reduced evaporation and improved soil moisture conservation compared with sole crops, particularly sorghum (Dhadge *et al*., 2014). Similar observations were made by Ghanbari *et al*. (2010).

Economic aspects of intercropping plants have also been revealed in research conducted in different countries of the world (Godoy and Bennett, 1991; Dhadge *et al*., 2014; Nazir *et al*., 2022; Yang *et al*., 2018; Chogatapur *et al*., 2018; Nemade *et al*., 2020; Akter *et al*., 2021; Baishya *et al*., 2021). No economic analysis was performed in this research. However, it is useful to evaluate the issue with the results of other research.

In a study conducted in India, a field experiment was carried out for Solapur Maharashtra to find out suitable geometry for sorghum + chickpea strip intercropping system on Vertisols under dryland condition. Among the various row proportions studied, sorghum + chickpea (3:3) at 45 cm row spacing system was found to be promising and registered significantly higher net returns (US$ 346/ha) (Dhadge *et al*., 2014).

In other study conducted in India, a field experiment on Integrated Nutrient Management in sorghum-chickpea cropping system was conducted to identify an ideal integration of organic and inorganic nutrient sources for getting maximum yield and monetary benefit with minimum input cost. The integration of organic and inorganic fertilizers were superior to inorganic treatments alone for both crops in sequence. Application of 75% RDN through inorganic fertilizer+ 25% RDN through FYM + seed treatment with PSB + Azospirillum to kharif sorghum and growing rabi chickpea without recommended dose of fertilizer recorded higher economic returns and B/C ratio of sole crop as well as system (Nemade *et al*., 2020).

A study conducted in Iowa, USA analyzes the biomass yield and economic potential of several high-yielding annual and perennial crops on prime and marginal, sloping land. The intercropping of the two sorghum species into reed canarygrass and alfalfa was also analyzed. Costs per ton for intercropped species were less than for either alfalfa or reed canarygrass, but were higher than costs per ton of monocrop sorghum. Although the sorghums had the highest yields, high potential for erosion on sloping soils may preclude their use on these soils (Hallam *et al*., 2001).

In a study conducted in China, it was investigated the effect of different maize densities and N rates on the growth, crop yields and economic benefits of pea (*Pisum sativum* L.)/maize (*Zea mays* L.) intercropping. The results indicated that total yields of pea/maize intercropping were higher than the yield of maize alone, and that pea/maize intercropping improved land use efficiency significantly compared to sole crops. Net returns and benefit to cost ratios of pea/maize intercropping were increased with an increase of maize planting density (Yang *et al*., 2018).

Conclusions and Recommendations

When studying the effect of fertilizer rates on the fodder quality of the green mass product obtained from the mixed sowing of sorghum and pea in stubble crops, it was calculated that there is a correlative relationship between the fodder unit obtained from one hectare and the dry matter. In general, the correct application of fertilizers and irrigation norms at the optimal level, and their timely delivery, significantly increased the quality indicators of the green mass product obtained from mixed sowings.

Organic and mineral fertilizers have a positive effect on the growth and development of mixed plants. During the research, we came to the conclusion that in order to obtain a high and quality yield from sorghum and pea plants, which are mixed with sorghum crops, it is appropriate to apply $N_{90}P_{120}K_{120}$ kg of mineral fertilizers per hectare, and manure of 10 t/ha + $N_{40}P_{95}K_{60}$ of organic and mineral fertilizers. $N_{90}P_{120}K_{120}$ kg of mineral fertilizers rates improve not only productivity but also product quality indicators. For successful fertilizer selection, it is necessary to know the condition of the soil in terms of concentrations of N, P, K and S elements and determine the most appropriate amounts. Carrying out the necessary maintenance work to protect the soil structure, minimize compaction and increase soil drainage also increases soil fertility. In addition, the fertilizer must be suitable for the plant type and must be applied at the right time, under the right climatic conditions and in the right place (Aygun *et al*., 2017).

As a result, fertilizer management studies that can ensure the use of appropriate fertilizer will support agriculture, reduce economic losses, increase production and reduce environmental pollution. In addition, it will contribute to reducing food imports and therefore CO_2 emissions and climate change adaptation efforts. In addition, evaluating and correlating different meteorological parameters in fertilization studies due to climate change will make it possible to reduce the spread rate and amount of fertilizer-related pollutants (Katip, 2020).

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Novelty Statement

The quality of the product is affected by plant genes as well as external environmental factors and growing conditions. Legumes are an important source of vegetable protein used in animal husbandry. It is suggested that one of the ways to increase the productivity of plants is the use of mixed crops consisting of legumes and grains in agrocenoses. Therefore, research aimed at increasing plant yield and quality can make significant contributions.

Author's Contribution

All authors contributed equally to the article. The results obtained in the study were interpreted together and all authors read and checked the article.

Conflicts of Interest

The authors have declared no conflict of interest.

References

Akter, H.A., P. Dwivedi., W. Anderson and M. Lamb. 2021. Economics of intercropping loblolly pine and oilseed crops for bio-jet fuel

production in the Southern United States. Agroforest Systems, 95: 241–255.

Allahverdiev, E. R., and S. F. Aliyeva. 2015. Influence of root residues and stubble residues on soil fertility. Scientific works of ASAU, Ganja, No. 2: 38-40.

Allahverdiev, E.R. 2020.The influence of organic and mineral fertilizers on the accumulation of nitrogen, phosphorus and potassium in the aerial part and alfalfa under covered sowing. J. Bull. Sci. Prac., 6(2): 151-157.

Allahverdiev, E.R. and D.A. Isaeva. 2021. Influence of watering rates and fertilizers on changes in the nutritional regime of the soil of mixed crops (sorghum and peas) by stubble. Agrar. Sci. J., 1:136-10.

Aygun, C., I. Kara., A. Sever., I. Erdogdu., A. Atalay., K. Ozaydın., H. Yildiz., O. Urla., M. Aydogdu., E. Unal., O. Aydogmus., F. Dedeoglu., M. Tugac., H. Torunlar., H. Cebel., O. Baskan., M. Kececı. and M. ve Bozkurt. 2017. Determination of nitrogen and phosphorus fertilizer requirements for Eskisehir province grasslands. J. Soil Water. 6(1): 44-51.

Azerbaijan State Statistical Committee (ASSC), 2024. Agricultural Statistics, https://www.stat.gov.az/?lang=en, Access Date: 23.06.2024.

Baishya, L.K., T. Jamir., N. Walling. and D.J. Rajkhowa. 2021. Evaluation of maize (*Zea mays* L.) + legume intercropping system for productivity, profitability, energy budgeting and soil health in hill terraces of Eastern Himalayan region. Legume Research, 44(11): 1343-1347.

Bao, S.D., 1999. Soil Agrochemical Analysis, China Agricultural Press, Beijing, China.

Beyyavas, V., S.N. Yilmaz., C.I. Cevher. and S. Cun. 2022. Effects of different fertilizer applications on yield, yield components and fiber quality in cotton (*Gossypium hirsutum* L.). Harran J. Agric. Food Sci., 26(3): 371-379.

Chogatapur, S.V., H.T. Chandranath. and R.B. Khandagave. 2018. Economics and intercropping indices of sugarcane based intercropping system in plant cane. Int. J. Curr. Microbiol. Appl. Sci., 7(8): 101-107.

Dahal, N.M., D. Xiong., N. Neupane., B. Zhang., B. Liu., Y. Yuan., Y. Fang., S. Koirala. and M.B. Rokaya. 2021. Factors affecting maize, rice and wheat yields in the Koshi River Basin, Nepal. J. Agric. Meteorol., 77:179-189.

Dhadge, S.M., N.R. Satpute., D.K. Kartmale., S.V. Patil., R.J. Gaijala., C.S. Rao., J.D. Jadhav. and J.R. Kadam. 2014. A study on sorghum (*Sorghum bicolor* L.) + chickpea (*Cicer arietinum*) Intercropping systems with varying row proportions on a semiarid vertisol. Ind. J. Dryland Agric. Res. Dev., 29(2):34-40.

Erdogdu, I., S. Altinok. and A. Genc. 2013. Effects of planting rates on some plant characteristics and feed efficiency in corn and soybean plants planted in different rows. Biol. Sci. Res. J., 6(1): 6-10.

Ghanbari, A., M. Dahmardeh., B.A. Siahsar. and M. Ramroudi. 2010. Effect of maize (*Zea mays* L.)-cowpea (*Vigna unguiculata* L.) intercropping in light distribution, soil temperature soil moisture and environment. J. Food Agric. Environ., 8:102-108.

Godoy, R. and C.P.A. Bennett. 1991. The Economics of Monocropping and Intercropping by Smallholders: The Case of Coconuts in Indonesia. Human Ecology, 19(1):83-98.

Gowda, B., T.N. Deepak., T.C. Suma., G.S. Yadahalli., S.I. Maccha. and S.M. Prashanth. 2020. Effect of intercropping and fertilizer dose on seed quality and physiological properties of chickpea (*Cicer arietinum* L.). Int. J. Curr. Microbiol. Appl. Sci., 9(1):591-601.

Hallam, A., I.C. Anderson. and D.R. Buxton. 2001. Comparative economic analysis of perennial, annual, and intercrops for biomass production. Biomass and Bioenergy, 21(2001):407-424.

Hu, X.P., Z.Q. Wang., N. Qi., T. Guo., Z.T. Liu. and R.C. Zhang. 1998. Application of gray dynamic model gm in the prediction of soybean yield. Heilongjiang agric. Sci., 6:20-23.

Jafarov, Y.A. and E.K. Mehdiyeva. 2014. Methods of agrochemical analysis. Baku, 264 p.

Kiriba, D., J. Msaky., N. Mahenge., P. Samwel., E. Kadeghe., P. Binagwa. 2020. Yield responses of bush bean varieties to different planting densities and rates of phosphorous fertilizer, Afr. J. Agric. Res., 15 (1):40-48.

Katip, A. 2020. Evaluation of chemical fertilizer consumption: the example of Bursa Province, Uludağ University. Journal of The Faculty of Engineering, 25(3):1271-1286.

Lee, J., E. Hoffland., T.W. Kuyper., Y. Yu., C. Zhang., H. Lee., F. Zhang. and W. Van Der Werf. 2020. Syndromes of production in intercropping impact yield gains. Nat. Plants, 6:653-660.

Lee, S., T.L. Lee., B. He., H. Jiao., Y. Lee., Z.C.

Lv. and J.F.Zhang. 2019. Effects of organic fertilizer instead of chemical fertilizer on water and nitrogen utilization and economic benefit of dryland wheat. Shanxi Agric. Sci., 8, 1359–1365.

Li, L, F. Chen. and G. Xing. 2022. Effects of fertilizer level and intercropping planting pattern with corn on the yield-related traits and insect community of soybean. Agronomy, 12(12):3080.

Liu, Q., H. Xu. and H. Yi. 2021. Impact of Fertilizer on Crop Yield and C:N:P Stoichiometry in arid and semi-arid soil. Int. J. Environ. Res. Public Health, 18(8): 4341.

Ludwig, B., D. Geisseler., K. Michel., R.G. Joergensen., E. Schulz., I. Merbach., J. Raupp., R. Rauber., K. Hu., L. Niu. and X. Liu. 2011. Effects of fertilization and soil management on crop yields and carbon stabilization in soils. A review. Agron Sustain Dev., 31:361-372.

Maja, M.M. and S.F. Ayano. 2021. The impact of population growth on natural resources and farmers' capacity to adapt to climate change in low-income countries. Earth Syst Environ., 5:271–283.

Nazir, M.S., A. Jabbar., I. Ahmad., S. Nawaz. and I.H. Bhatti. 2002. Production potential and economics of intercropping in autumn-planted sugarcane. Int. J. Agric. Biol., 4(1):140-142.

Nemade, S.M., N.B. Mohod., G.J. Bhagat., V.R. Thakur., D.T. Dhule. and M.M. Ganvir. 2020. Economics of sorghum-chickpea cropping system as affected by integrated nutrient management (INM) under Rainfed Conditions. Int. J. Curr. Microbiol. Appl. Sci., 9(03): 2957-2962.

Xiao, J., X. Yin., J. Ren., M. Zhang., L. Tang. and Y. Zheng. 2018. Complementation drives higher growth rate and yield of wheat and saves nitrogen fertilizer in wheat and faba bean intercropping, Field Crop. Res., 221:119–129.

Yang, C., Z. Fan. and Q. Chai. 2018. Agronomic and economic benefits of pea/maize intercropping systems in relation to n fertilizer and maize density. Agronomy, 8, 52.

Yang, J. X., R. A. Richards., Y. Jin. and J. He. 2022. Both biomass accumulation and harvest index drive the yield improvements in soybean at high and low phosphorus in southwest China. Field Crop. Res., 277(1):108426.

Yu, G., F. Chen., Y.H. Xie.and J.W. Howe. 2020. Effects of reduced application of chemical fertilizer and combined application of organic fertilizer on yield and quality of hot pepper. North. Hortic. 4: 47-53.

Zhao, Y., X. Liu., J. Tong. and Y. Wu. 2020. Effect of root interaction on nodulation and nitrogen fixation ability of alfalfa in the simulated alfalfa/triticale intercropping in pots. Sci. Rep. 10, 4269.

Zhang, Z.H., J.A. Palta., P. Lu., M.J. Ren., X.T. Zhu. and J. He. 2022. Traditional soybean (*Glycine max*) breeding increases seed yield but reduces yield stability under non-phosphorus supply. Funct. Plant Biol., 49: 132-144.