Effect of Adding Potassium and Organic Fertilizers on the Readiness of Potassium in the Soil and the Productivity of Yellow Corn

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Abstract: The research was carried out on a private farm in Deir Ezzor Governorate during the summer season of 2022 with the aim of studying the effect of adding potassium fertilizer and organic fertilizer on potassium readiness in the soil and the productivity of yellow corn, Ghouta 82 variety. The method of factorial experiments was used in designing the experiment according to a randomized complete block design (RCBD) with three replications. The results showed: an increase in the soil content of soluble and available potassium at the fourth level of potassium fertilizer (200 kg K ha^{-1}) compared to the other levels, while adding organic fertilizer led to an increase in the soil content of soluble and available potassium at the fourth level (25 tons ha^{-1}), as for plant characteristics (fresh weight of shoots, chlorophyll, grain yield), we notice that the fourth level of potassium fertilizer is superior to the rest of the levels, as well as the fourth level of organic fertilizer is superior to the rest of the levels and to the control. The interaction of the two fertilizers also had a positive effect on the content of the soil contains potassium, and the best results were at the fourth level of potassium fertilizer and the fourth level of organic fertilizer. As for the studied plant characteristics, the interaction of the fourth and third levels (150 kg K ha^{-1}) of potassium fertilizer with the fourth level of organic fertilizer achieved a significant superiority over the rest of the levels.

Keywords: soluble potassium, available potassium, organic fertilizer, vegetative growth, grain yield.

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1 Introduction

Yellow corn (*Zea mays* L.) occupies a wide area in the world and is considered one of the crops of nutritional importance all over the world in addition to its high production. It is ranked third after wheat and rice in terms of importance as a grain crop (Zaidan et al., 2019). The importance of the yellow corn crop lies in two points: the first is its use in human and animal nutrition due to the presence of a good percentage of oil in the grains, ranging from (4%-10%), and the second is its high production capacity and its adaptation to climatic conditions (Mandić et al., 2016). The economic importance of yellow corn is due to its grains containing a high percentage of protein, (10.6%), oil, (4.6%), and carbohydrates, (81%), in addition to the grains containing vitamins B1, B2, and E (Sachin and Misra, 2009). A number of food products are made from its

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grains that are used in human nutrition. Or in the manufacture of oil and dextrin. It is also used in many industrial fields, including the manufacture of dyes, ceramics, paper, and cork. Corn production is affected by poor soil fertility, which requires adding fertilizers to meet the crop's need for nutrients. (Aljoubory and Al-Yasari, 2023). One of the most important requirements for achieving the highest yield in agriculture is ensuring appropriate levels of nutrients in the soil, including potassium, as the plant needs it at all stages of its growth.

It is an important element in soil fertility and plant nutrition, a function of many physiological processes in the plant, and a specific nutrient for production (Ali et al., 2014). Despite the relatively large store of potassium in the soil, the speed of its release is relatively slow and is not sufficient to meet the needs of many crops, especially in conditions of intensive agriculture and crops with high requirements for this element (AI-Zubaidi, 2003). The amount of potassium that the plant needs varies depending on Type, variety, growth stage, and quality of grains or fruits produced (Ali et al., 2014). Potassium plays a vital role in the functioning of photosynthesis enzymes and the production of protein and carbohydrates, as well as reducing resistance to diseases and pests. The reason for this is due to the role of potassium in forming a thick cell wall (EL-Shal, 2016). One of the most important functions of potassium for plants is to maintain the balance of positive and negative ions in the cell juice (Amrutha et al., 2007). Ibrahim et al. (2023) confirmed that the addition of potassium fertilizer led to an increase in dissolved and exchangeable potassium in the soil and an increase in (plant height, cob, number of cob, number of cob rows, stalk weight, and whole plant weight) of yellow corn.

Organic fertilization is the cornerstone that must be put in place to raise soil fertility and production and reduce environmental pollution resulting from the excessive use of mineral fertilizers. Adding organic waste to the soil has a role in increasing the readiness of potassium as a result of replacing the potassium ion K^+ on surfaces with the hydrogen ion H+ resulting from the dissolution of organic acids (Delphi, 2013). Song et al. (2009) indicated that organic matter has a role in dissolving some minerals and compounds containing potassium through organic acids resulting from their decomposition, in addition to that organic matter is a direct source of potassium in the soil. Aboutayeb et al. (2014) found that adding organic fertilizer at a level of 15 tons ha^{-1} had a significant effect in increasing the amount of ready potassium in the soil, which reached 350 mg kg^{-1} compared to the control treatment, which amounted to 277 mg kg^{-1}. Several studies were conducted to determine the response of yellow corn to organic fertilization, as Eleduma (2020) indicated that adding organic fertilizers at the level of (5, 10, 15, 20) tons ha^{-1} achieved a significant increase, and that the level of 20 tons ha^{-1} gave a significant increase in all growth and productivity characteristics. For yellow corn plants. Gomaa et al. (2020) also explained that adding organic fertilizers (sheep waste) at the level of (0, 10, 20) m^3 dunums achieved a significant increase, and that the level of 20 m^3 excelled by giving the highest averages for the characteristics of the cob length, the number of rows in the cob, the number of grains in the row, and the weight of 100 Grain, grain yield, biological yield, harvest index, and protein content in grains.

The presence of calcium ions in high quantities in the soil solution relatively hinders the absorption of potassium ions, and the presence of clay minerals has a high ability to stabilize the potassium present in a ready form and convert it to the slow-ready form for the plant, which called for the necessity of preserving potassium in its ready form by adding fertilizers. Potassium to the soil. In addition to the role that organic matter plays in increasing the availability of macro- and micronutrients, and because of their low percentage in the soil of dry climates for many reasons, raising the soil content of organic matter is extremely important. Given the economic importance of the yellow corn crop, its good yield, and its response to adding fertilizers, our research came to achieve the goals. The objects of this study include:

(1) Studying the effect of adding potassium fertilizer on increasing the readiness of potassium in the soil and the productivity of yellow corn and determining its optimal concentration.

(2) Study the effect of adding organic fertilizer on increasing potassium readiness in the soil and yellow corn productivity and determining the optimal concentration.

(3) Study of the mutual effect of potassium fertilizer and organic fertilizer in increasing the readiness of potassium in the soil and the productivity of yellow corn.

2 Materials and methods

2.1 Research materials

2.1.1 Place where the research was carried out

The research was carried out in the Al- Agawat area in Deir Ezzor Governorate during the 2022 season.

2.1.2 Plant material

The yellow corn plant, Ghouta 82 variety, was used, obtained from the Seed Multiplication Center in Deir Ezzor.

2.1.3 Fertilizers used

Four levels of potassium fertilizer were added (0 - 100 - 150 - 200) kg K ha^{-1} in the form of potassium sulfate K_2SO_4 (50% K_2O), which was added to the soil before planting.

Organic fertilizers (fermented sheep waste) were added at four levels (0 - 15 - 20 - 25) tons ha^{-1}. The organic fertilizer was mixed with the surface layer of the soil before planting for each experimental unit.

2.2 Working methods

2.2.1 Preparing the land for agriculture

The land was plowed, smoothed, and divided into three sectors. Each sector into 16 experimental units. Each experimental unit contained three lines (each line was 3 m long and the distance between one line and the other was 70 cm). A distance of 1 m was left between the experimental units, and 2 m between the sectors. The area of the experimental plot was 6.3 m^2, i.e. With dimensions of (3 × 2.1) m^2, then the experiment was planted with the yellow corn crop at a depth of 5 cm and a distance of 25 cm between the holes. Planting took place on 21/6/2022, and three seeds were placed in one hole, and they were reduced to one plant after germination.

2.2.2 Fertilizers added

Phosphate fertilizers, 170 kg of superphosphate fertilizer, 46% phosphorus, were added per Hectare before planting, and nitrogen fertilizers, 120 kg N ha^{-1}, in the form of fertilizer (urea 46%) were added in two batches: The first batch, 60 kg ha^{-1}, before planting is equivalent to 130 kg. Urea 46%, second batch 60 kg N ha^{-1} at the beginning of the male inflorescence formation stage, in accordance with the recommendation of the Ministry of Agriculture according to soil analysis.

2.2.3 Soil-related indicators before planting

Composite soil samples representative of the research site were taken, and after drying the soil samples and cleaning them from root residues, they were ground and sieved using a sieve with a diameter of 2 mm, and chemical analyzes were conducted for them, electrical conductivity (ECe) (dS m^{-1}) using an electrical conductivity device. The degree of soil reaction (pH) using a pH-meter, organic matter using the wet oxidation method, mineral nitrogen using the Kjeldahl method, available phosphorus using the Olsen method, and using a spectrophotometer, potassium using a flame spectrophotometer device.

3 Studied attributes and characteristics

Dissolved potassium (mg kg^{-1}): flame spectrophotometer.

Available potassium (mg kg^{-1}): flame spectrophotometer.

Fresh weight of shoots (g). Only the stem and leaves were weighed, not the fruits and roots.

Chlorophyll measurement: The chlorophyll content in leaves was measured in the field using the SPAD device.

Grain yield tons ha^{-1}: At the end of the growing season, each treatment was harvested. The grain yield was calculated.

Table 1 Chemical properties of the soil before planting and the organic fertilizer used in the research

Chemical properties of soil before planting		Basic characteristics of the organic fertilizer used	
ECe (dS m^{-1})	0.63	EC (dS m^{-1})	12.92
pH_{KCl}	7.9	pH	7.25
organic matter%	0.76	organic matter%	51.6
N mg kg^{-1}	4.6	Organic carbon%	30
$^{P-12O\ 5}$mg kg	6.9	N%	1.72
K mg kg^{-1} disposable	217	P%	0.96
K mg kg^{-1} dissolved	12	K%	1.43

4 Experiment design and statistical analysis

In designing the experiment, the method of factorial experiments was used according to a randomized complete block design (RCBD) with three replicates and a rate of 36 plants per replicate, to study the effect of both the first factor, potassium fertilizer rates, and the second factor, organic fertilizer rates, and their interaction, and thus required the implementation of the experiment. 48 experimental plots, the results were analyzed statistically using the ANOVA method by calculating the value of the least significant difference (LSD) at the level 5% for field results and the level 1% for laboratory results using the statistical program GenStat 12 th.

5 Results and discussion

5.1 Soluble potassium

The results of Table 2 show that there was a significant increase in the concentration of dissolved potassium in the soil at the fourth level 200 kg K ha^{-1}. Its value reached 31.92 mg kg^{-1}, followed by levels with a lower value, respectively. The value decreased significantly in the control to 14.27 mg kg^{-1} The increase is due to the addition of potassium fertilizer, which in turn led to an increase in the soil's available potassium content, and this is consistent with (Ibrahim et al., 2023).

Table 2 Effect of adding potassium and organic fertilizer on soluble potassium in the soil mg kg^{-1} after harvest

Potassium fertilizer kg ha^{-1}	Organic fertilizer tons ha^{-1}				Average potassium fertilization treatments
	0	15	20	25	
0	6	11.84	17.05	22.19	14.27d
100	13.32	16.72	21.06	26.14	19.31c
150	19	25.43	29.11	32.02	26.39b
200	26.71	29.36	33.79	37.85	31.92a
Average organic fertilization treatments	16.25d	20.83c	25.25b	29.55a	22.97
LSD1% for potassium fertilizer	4.46				
LSD1% for organic fertilizer	3.72				
LSD1% for reaction	3.92				

The results also indicate an increase in the value of soluble potassium with increasing levels of organic fertilizer, with significant differences between all levels. The highest value reached 29.55 mg kg^{-1} at the fourth level 25 tons ha^{-1}, while the lowest value was at the control 16.25 mg kg^{-1}, which is attributed to increase dissolved potassium in the soil plays a role in organic fertilizer after its decomposition in producing many organic acids with the ability to dissolve some potassium-bearing compounds and minerals on the one hand, and the possibility of organic matter entering between the layers of clay on the other hand, in addition to the formation of organic complexes with the added potassium, which reduces the loss of potassium. Fertilizer due to the regulating capacity of the soil, thus releasing potassium into the soil solution, and this result is consistent with the findings of (Bader et al., 2021).

As for adding potassium and organic fertilizer together, the highest value was reached when the fourth level of potassium fertilizer 200 kg K ha^{-1} was mixed with the fourth level of organic fertilizer 25 tons ha^{-1}, and it was 37.85 mg kg^{-1}, while the value decreased significantly for the control 6 mg kg^{-1}.

5.2 Available potassium

The data presented in Table 3 indicate an increase in the concentration of available potassium in the soil with increasing levels of added potassium. The highest value reached at the fourth level 200 kg K ha^{-1} and was 299.83 mg kg^{-1}, while the value decreased significantly in the control to 227.83 mg kg^{-1} and this increase is a result of adding potassium fertilizer, and this is consistent with (Khuspe et al., 2015).

The results also show that there was a significant increase when adding the fourth level 25 tons ha^{-1} of organic fertilizer in terms of available potassium compared to the rest of the levels, where its value reached 292.34 mg kg^{-1}, while the value decreased significantly in the control 241.15 mg kg^{-1}. The reason for this is the significant effect of organic fertilization in increasing the concentration of ready potassium in the soil as a result of replacing the H^+ ion resulting from the dissolution of organic acids resulting from the decomposition of organic fertilizer with the K^+ ion on the exchange surfaces of the soil in addition to the potassium contained in the organic fertilizer. The role of organic fertilizer in dissolving some compounds and minerals that carry it are induced by organic acids, and this result is consistent with his findings (Bader et al., 2021).

On the other hand, the interaction of potassium and organic fertilizers affected the soil content of available potassium. The highest value was reached when the fourth level of potassium fertilizer 200 kg K ha^{-1} was intermingled with the fourth level of organic fertilizer 25 tons ha^{-1}, and it was 326.12 mg kg^{-1}, while the value decreased significantly in the control 189.26 mg kg^{-1}.

Table 3 Effect of adding potassium and organic fertilizer on available potassium in the soil mg kg^{-1} after harvest

Potassium fertilizer kg ha^{-1}	Organic fertilizer tons ha^{-1}				Average potassium fertilization treatments
	0	15	20	25	
0	189.26	221.93	241.33	258.82	227.83d
100	240.62	250.08	262.03	280.95	258.42c
150	258.87	271.55	287.5	303.47	280.34b
200	275.86	288.44	308.53	326.12	299.73a
Average organic fertilization treatments	241.15d	258c	274.84b	292.34a	266.58
LSD1% for potassium fertilizer	17.82				
LSD1% for organic fertilizer	15.47				
LSD1% for reaction	16.01				

5.3 Fresh weight of shoots

From the data presented in Table 4, we conclude that there is a significant increase in the fresh weight of the vegetative plant when adding the fourth level 200 kg K ha^{-1} of potassium fertilizer, as it reached 493.70 g compared to the other levels and the control 442.78 g. We also notice an increase in the fresh weight. With high levels of potassium fertilizers, this increase can be explained by the role of potassium in delaying leaf senescence in addition to its role in good vegetative growth, which reflects positively on the process of photosynthesis and thus increases cell division, which leads to an increase in leaf area on the one hand, and its role in increasing the height of the plant and increasing the number of leaves. The papers, on the other hand, agree with this result (Fatima et al., 2014).

The results also indicate an increase in fresh weight with high rates of organic fertilizer. The highest value of fresh weight was reached at the fourth level 25 tons ha^{-1}, with a significant difference 503.52 g compared with the rest of the fertilizer treatments and with the control in which the fresh weight decreased significantly to 435.87 g This is due to the positive role of organic fertilizer on plant growth and production because it contains essential nutritional elements that contribute to increasing the process of photosynthesis, which leads to increased growth of the vegetative system, and this is consistent with (Patil et al., 2017).

As for the mutual effect of both potassium and organic fertilizers, the interaction at high levels of both fertilizers achieved increased fresh weight values. The highest value was reached at the fourth treatment

200 kg K ha^{-1} for potassium fertilizer and the fourth treatment 25 tons ha^{-1} for organic fertilizer, and there was no difference between them and the third treatment 150 kg K ha^{-1} for potassium and the fourth treatment for organic fertilizer overlapped, meaning there were no significant differences, which were respectively 524.17-520.95 g, while the weight value decreased significantly in the control, as it reached 412.26 g.

5.4 Chlorophyll content of leaves

The results of Table 5 show that the potassium fertilization treatment at the fourth level 200 kg K ha^{-1} was superior to the rest of the treatments in the chlorophyll content of the leaves, reaching 55.16 SPAD, while the chlorophyll content of the leaves in the control decreased to 45.67 SPAD. The reason for the increase is due to the role of Potassium affects the hormones that stimulate the formation of chlorophyll in the leaf and increases its content. Among these hormones is cytokinin, which is necessary for the emergence of chloroplast during leaf growth and development. These results are consistent with what was found (Gnanasundari et al., 2019).

Table 4 Effect of adding potassium and organic fertilizer on the fresh weight of the shoots g

Potassium fertilizer kg ha^{-1}	Organic fertilizer tons ha^{-1}				Average potassium fertilization treatments
	0	15	20	25	
0	412.26	431.60	456.58	470.71	d442.78
100	420.17	452.51	463.93	498.25	c458.71
150	442.40	460.12	488.75	520.95	b478.05
200	468.65	481.01	500.99	524.17	a493.70
Average organic fertilization treatments	d435.87	c456.31	b477.56	a503.52	468.31
LSD5% for potassium fertilizer	13.42				
LSD5% for organic fertilizer	18.67				
LSD5% for reaction	16				

Table 5 Effect of adding potassium and organic fertilizer on the chlorophyll content of leaves SPAD

Potassium fertilizer kg ha^{-1}	Organic fertilizer tons ha^{-1}				Average potassium fertilization treatments
	0	15	20	25	
0	36.34	43.11	49.67	53.58	45.67d
100	42.80	46.93	51.58	55.17	49.12c
150	47.76	48.89	54.14	58.91	52.42b
200	51.69	53.06	56.23	59.67	55.16a
Average organic fertilization treatments	d44.64	c47.99	b52.90	a56.83	50.59
LSD5% for potassium fertilizer	1.67				
LSD5% for organic fertilizer	2.90				
LSD5% for reaction	2.31				

As for the organic fertilization treatments, the chlorophyll content of the leaves increased with increasing levels of organic additives. The fourth level 25 tons ha^{-1} achieved the highest chlorophyll value 56.83 SPAD compared to the rest of the treatments and the control 44.64 SPAD. This increase is due to the role of organic fertilizers in providing nutrients in sufficient quantities, which have an important role in manufacturing chlorophyll in the leaves, and increasing cytokinin and auxin, which increase the physiological activities of the leaves and lead to an increase in the chlorophyll content in them. This result is consistent with (Faisal et al., 2013).

The results also show a noticeable increase in the chlorophyll content of leaves in the high fertilizer interactions. The highest value of chlorophyll was reached when the third level 150 kg K ha^{-1} and fourth level 200 kg K ha^{-1} of potassium fertilizer were mixed with the fourth level 25 tons ha^{-1} of Organic fertilizer was 58.91 - 59.67 SPAD, while it decreased significantly in the control 36.34 SPAD.

5.5 Grain yield tons ha^{-1}

It is clear from the data in Table 6 that there was a significant increase in the grain yield of yellow corn at the fourth level of potassium fertilizer 7.49 tons ha^{-1} compared with the other levels and with the control that recorded the lowest grain yield 5.13 tons ha^{-1}. The results also show that if potassium increases, grain yield increases. This may be due to the availability of potassium during the grain formation stage, or to the role of potassium in activating many enzymes, as well as to its role in building amino acids and proteins, as well as transporting carbohydrates, which increases the efficiency of photosynthesis and thus leads to an increase in grain yield, or the increase is due to the role of potassium in increasing the number of grains in the grain. Grade and grain weight, which reflected positively on grain yield, and this result is consistent with (ul-haq et al., 2019).

As for organic fertilizer, the fourth level recorded the highest grain yield 7.72 tons ha^{-1}, followed by the third level, followed by the second level, with significant differences between all levels and the control in which the yield decreased to 4.78 tons ha^{-1}. This may be attributed to the role of organic matter in improving properties. The physical and chemical properties of the soil, thus increasing the availability of nutrients and thus their absorption by the plant and their transfer to storage places, which are the seeds. This result is consistent with the findings of Çokkizgin et al. (2022) and Eleduma et al. (2020).

The results also indicate an increase in grain yield at all levels of interaction compared to the control, which recorded the lowest value 3.22 tons ha^{-1}. The highest value was reached when the fourth level of potassium fertilizer was intermingled with the fourth level of organic fertilizer 8.36 tons ha^{-1} and there was no the third level of potassium fertilizer and the fourth level of organic fertilizer interacted, meaning a significant difference 8.32 tons ha^{-1}, followed by the rest of the interactions.

Table 6 The effect of adding potassium and organic fertilizer on the grain yield of yellow corn, tons ha^{-1}

Potassium fertilizer kg ha^{-1}	Organic fertilizer tons ha^{-1}				Average potassium fertilization treatments
	0	15	20	25	
0	3.22	4.75	5.97	6.57	5.13d
100	3.99	5.98	6.02	7.64	5.91c
150	5.62	6.62	7.87	8.32	7.10b
200	6.29	7.31	8.01	8.36	7.49a
Average organic fertilization treatments	4.78d	6.16c	6.97b	7.72a	6.41
LSD5% for potassium fertilizer			0.21		
LSD5% for organic fertilizer			0.37		
LSD5% for reaction			0.28		

6 Conclusions and recommendations

Adding potassium fertilizer at the fourth level 200 kg K ha^{-1} increased the soil content of soluble and available potassium and also led to an increase in the fresh weight of the shoots, chlorophyll, and grain yield.

The effect of organic fertilizer in increasing the soil content of Soluble and available potassium at the fourth level 25 tons ha^{-1}, and in increasing the fresh weight of the shoots, chlorophyll, and grain yield.

The interaction between potassium and organic fertilization levels had a positive effect on all the studied soil and plant characteristics.

From the above, it can be recommended to use the third level 150 kg K ha^{-1} of potassium fertilizer with the fourth level of organic fertilizer 25 tons ha^{-1}, which gave the best results for the corn crop. It is suggested to use other levels and apply them to other crops.

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