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Quantitative and Qualitative Responses of Corn 704 Singel-Cross to Different Planting Patterns and Nitrogen Fertilizer Levels

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KEYWORDS

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ABSTRACT: In this study, an experiment was conducted to evaluate the effect of planting pattern and different amounts of nitrogen on the quantitative and qualitative yield of maize based on split plot design with randomized complete block design in Salmanabad area, Pishva city, Tehran. The factors included planting pattern as the main factor in single-row and double-row cultivation, and the sub-factors were different amounts of urea fertilizer at four levels (zero), 120, 240, and 360 kg urea per ha. First, the highest plant height, ear height from ground level, leaf area index, grain yield, nitrogen percentage of shoot, seed, and soil after harvest, crude protein percentage were obtained by consuming 360 kg urea per ha. Maximum stem diameter, ear diameter, number of rows per ear, number of seeds per row, ear weight per plant, and shoot nitrogen percentage were observed in the single row cultivation method, while maximum plant height, ear height above ground, leaf area index, and crude fiber percentage was reported in the double-row cultivation. In addition, the single row cultivation under the application of 360 kg urea per ha led to the highest number of grain per row and grain yield (34.6 and 13784.6 kg ha^{-1}, respectively) compared to the control treatment increased by 13.5 and 37.4%, respectively. The increasing levels of urea fertilizer indicated a significant increase in nitrogen percentage of seed, shoot, and soil after harvest. Further, the highest mean percentage of shoot nitrogen (1.89%), seed (2.05%), and post-harvest soil (0.13%) was observed under 360 kg urea per ha treatment. Additionally, maximum digestible dry matter (DMD) was obtained in double row cultivation and the use of 360 kg urea per ha with an average of 53.05%, which was 8.55% more than the control treatment. Furthermore, thee highest amount of crude protein was observed in single row culture (19.27%) and the use of 360 kg urea per ha (20.20%). Based on the results, the regression model was significant and 78.54% of the grain yield variations were justified by stem diameter, leaf area index, ear length, and 1000-seed weight. In general, using the methods of single row for grain production and double row for age production cultivation under 360 kg urea per ha yielded the most favorable results.

INTRODUCTION

Cereals are the main crop and occupy a large area of the most important parts of the world. About 55% protein, 15% fat, 70% glucose, and 50-55% of the calories consumed by humans in the world are provided by grains. Corn (*Zea mays* L.) is a plant of the wheat family (*Gramineae* or *Poaceae*), a subfamily of Panicoideae, which ranks the first in terms of production and second based on the area under cultivation after wheat [1, 2].

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Planting patterns affect the proper and better distribution of light within the canopy. Therefore, the main effect of planting distance on the crop is mainly related to the differences in how solar radiation is distributed, and increased radiation absorption leads to increased yield. In this regard, the corn planting method is the most important agricultural activity to achieve maximum yield [3].

In double-row planting arrangements, a more suitable distance and space is provided for each plant to benefit from light, moisture absorption, fertilizer, and other nutrients. In this planting pattern, a decrease in the number of irrigated runnel, as well as a reduction in water evaporation and waste level leads to an increase in the efficiency of irrigation and water consumption [3]. Different studies have been conducted on some crops, some of which used this pattern in some useful crops and some rejected this pattern [4, 5].

Nitrogen is considered as one of the most important components of chemical fertilizers, which is important in soil fertility. This element is available in the structure of various compounds such as chlorophylls, nucleic acid, protein, and most of the vitamins which play an important role in the physiological processes of the plant [6]. The average efficiency of nitrogen use in the world for cereals is 30 to 33%, which is 29 and 42% for the developing and developed countries, respectively [7, 8].

Corn yields in most arid and semi-arid regions of the country are low due to low soil organic matter and nitrogen deficiency. This problem should be solved by using nitrogen fertilizers. Unfortunately, these fertilizers have not been used effectively and their efficiency is low [9]. If the nitrogen used is more or less than the plant needs, it disrupts the vital processes of the plant, which can occur in various forms such as high growth, decrease, delay or even the cessation of reproductive growth and jaundice of the plant [10].

Nitrogen fertilizers significantly increase plant weight, root length, nitrogen content, and grain yield [11]. Some reported that nitrogen deficiency causes premature aging of the leaves and has a negative effect on plant photosynthesis process, especially by affecting RUBP carboxylase (plant photosynthesis, by lowering the leaf area index (LAI), as well as protein synthesis and degradation [12]. Nitrogen consumption affects growth, leaf surface production capacity, and plant photosynthetic capacity so that the rate of photosynthesis at the leaf area of corn decreases by decreasing nitrogen levels. In addition, grain yield, grain weight, number of grains, and other components of yield are significantly influenced by nitrogen treatment [13, 14].

Some scientists believe that increasing the yield of a single plant by nitrogen consumption may be associated with an increase in the number of seeds per ear or an increase in the weight of a thousand seeds [15]. Further, an increase in nitrogen leads to a increase in the amount of grain protein and a decrease in the biological value of the protein. Some experiments have shown that nitrogen affects the quantity and quality of seeds. Some reported that nitrogen can increase grain protein [16]. Sharifi et al. [17] showed that the effect of nitrogen on the grain protein percentage is significant and increases the percentage of the grain protein. In addition, the production of intensified protein substances, plant growth accelerates, and their aging slows down when the amount of nitrogen fertilizer is optimal in plant nutrition [18].

In Iran, corn, after wheat, barley, and rice has the highest area under cultivation among cereals. Reviewing and finding solutions to increase quantitative and qualitative corn is one of the priorities of agricultural research since corn has a high rank in terms of importance in human and animal nutrition program, high production capacity of corn, and high per capita consumption of this product in different countries. In this regard, agricultural operations play a role in increasing the quantity and quality of seeds, and the proper selection of methods for agriculture and their application can have a positive effect on increasing these two important components. Based on the above-mentioned cases, this study aims to evalaute the effect of planting pattern and nitrogen fertilizer and their interaction on physiological traits, yield, and yield components of corn in Varamin region.

MATERIALS AND METHODS

A spilt-plot experiment was performed based on a basic design of complete random blocks with three replications in order to study the effect of planting pattern and different levels of nitrogen fertilizer on some quantitative and qualitative traits of corn. Planting pattern treatment at single and double row levels in the main plots and nitrogen from the urea source at four levels (0, 120, 240, and 360 kg ha^{-1}) were placed in the sub-plots. The present study was conducted in Salmanabad region located in Pishva city (south of Tehran province) in latitude 35 degrees and 19 minutes and longitude 51 degrees and 39 minutes, altitude 915 meters. This region is located on the edge of the desert plain, has a warm and dry climate, and the average long-term rainfall of the region is 151.7 mm.

A combined sampling test was performed before planting in order to determine the physical and chemical condition of the soil from the depth of zero to 30 cm of the soil, the results of which are presented in Table 1. Each plot consisted of three rows of crops with the length of 4 meters. The distance was considered between the rows of 65 cm in single-row cultivation and 32.5 cm in double-row cultivation. The distance between the plants on the row was 10, and 20 cm in single-row and double-row cultivation, respectively. Cultivation was done manually in the dry season in July and three seeds were placed at a depth of 3 cm, which were thinned in three to four leaf stages. There was a distance of 1 m between the main plots and 2 m between the repetitions. The cultivar of corn tested in this experiment was Single Cross 704 (KSC 704), which was prepared by Varamin Agricultural Research Center and its weight of 1000 seeds is 272.94 g, late and resistant to pests and diseases.

Table 1. Physico-chemical properties of the soil from a depth of 0-30 cm

Texture	**K**	**P**	**N**	**OC**	**TNV**	**pH**	**EC**	**Depth**
-	**(%)**	**(%)**	**(%)**	**(%)**	**(%)**		**(dS m^{-1})**	**(cm)**
Loam	4.59	40	0.13	1.3	23.71	7.15	7.35	**30-0**

The first irrigation was performed according to the custom of the region 2 days after cultivation and then every 5-7 days. Irrigation was carried by drip with the help of T-tape pipes. There was a draper with a flow rate of 1.2 liters per hour for every 10 cm for single-row cultivation and every 20 cm for double-row cultivation. Common weeds on the farm included Nut grass (*Cyperus rotundus*), Purslane (*Portulaca oleracea*), and Amaranth (*Amaranthus*). In this experiment, the weed was controlled up to the 10-leaf stage only by manual weeding, which became superior to other plants after that stage due to the shading of corn. The experimental plots were fertilized based on soil testing and laboratory recommendations in the form of rotten manure 5 tons per hectare at the time of soil preparation, 300 kg of sulfur per hectare, 120 kg of ferrous sulfate per hectare, 40 kg of zinc sulfate per hectare, 20 kg copper sulphate per hectare, 20 kg of manganese sulfate per hectare, 10 kg of boric acid per hectare, 50 kg of magnesium sulfate per hectare, and the amount of nitrogen used based on the test map in each plot. During the irrigation period, the fertilizers were given to the plant along with the irrigation tank with irrigation water, with the exception of urea fertilizer, which was distributed manually (strip) per plot for each plant. The amount of urea was given to the plant separately for each plot in 10 leaves of the plant, in the middle of vegetative growth, and before flowering.

Sampling was perfomed for measuring quantitative traits, 5 plants per plot of 10 cm above ground level with respect to the marginal effect and wet and dry weight traits of stems, leaves, flowers, seeds and wood of ears, as well as plant height, leaf area meter (AM-300), stem diameter, ear diameter, ear length, ear weight, number of rows per ear, number of seeds per row, number of leaves above the main ear, and ear height from the ground surface.

A heavier weight was recorded separately after separating the specimens into stems, leaves, flowers, seeds, and ear wood with a digital scale. Then, the stems, leaves, flowers, seeds, and sticks of ear were dried in an oven at 48°C separately for 48 h and weighed to determine the dry weight. In addition, the harvest index (ear dry weight to total dry weight) was calculated [19]. In order to measure the quality traits of forage, two plants from the middle line were randomly selected and dried the aerial parts in the shade, which was then rinsed with distilled water to completely remove the dust and ground after the specimens had dried after removing the two side lines and 50 cm from the top and bottom of the plot as a marginal effect. The forage quality indicators include Dry Matter Digestibility (DMD), Crude Protein (CP), Acid Detergent Fibr (ADF), Ash, and Water Solduble. Further, Carbohydrate (WSC) was measured using NIR (Near Infrared Reflectance Spectroscopy) at the Forest and Rangeland Research Institute.

To measure the percentage of plant nitrogen, 0.3 g of the plant sample was weighed with an accuracy of 0.001 g and transferred to the digestive tubes (jelly balloon 100 ml), and then 2.5 ml of the acid mixture was added after 24 h. In the next step, the pipes were heated to 180 ^{o}C for 2 h, and then, after cooling, three times, 1 ml of oxygenated water was added to the pipes each time, again the pipes on the heater to 330 ^{o}C. In addition, the centipede was put for 3 h until the extract is colorless. The extract was delivered to the balloon in a volume of 100 ml, from which 5 ml was taken and transferred to the distillation balloon. Furthermore, 3 ml of sodium hydroxide solution was added and the distillation hopper of the distillation balloon was rinsed with water to make the volume of the solution 20 ml. The balloon was heated with water vapor and continued for n minutes (3-4-5 or 6 min) after the first drop of distillation. The distillation solution was absorbed in 10 ml of boric acid containing 10 drops of the indicator. Then, the boric acid content slightly reduced to wash the end of the refrigerant with water vapor 0.5 min before the end of the Erlenmeyer distillation operation. Boric acid containing ammonia was titrated with sulfuric acid to 0.005 mol until the color of the solution changed from green to pink. The percentage of nitrogen in the dry plant sample was calculated from the following equation (1):

$$0.56 \times t \times (a-b) \times V / M \times 100 / D.M \quad (1)$$

Where: t shows the concentration of acid used for titration per mole per liter, A indicates the amount of acid used for the sample in ml, and B is the amount of acid used for control in ml.

After harvesting the soil, 10 g of previously dried soil was poured into a 250 ml plastic container and 100 ml of 2 moles of potassium chloride was added to. Then, the container was closed and put in the rotary shaker for 1 h, and the samples were left to stand for 30 min until it settled. SAS statistical software version 9.2 was used for data analysis. Finally, Duncan's multiply test was used comparing the means.

RESULTS AND DISCUSSION

Growth and yield characteristics

Based on the results, the effect of planting pattern on plant height, stem diameter, leaf area index, first ear height from ground, ear diameter and number of seeds per row was significant, along with, the effect of urea fertilizer on plant height, leaf area index, ear height from ground, ear diameter, grain yield, and fresh forage yield at 1% probability level (Table 2). As shown in Table 3, the double-row cultivation led to an increase of 18.3, 8.97, 4.06, and 7.19% for the average plant height, leaf area index, first ear height above ground, and 1000-seed weight compared to the amounts in the single-row cultivation.

Regarding the increase in leaf area in the double-row cultivation, it seems that the proper arrangement of plants in corn leads to the optimal use of environmental conditions, which resulted in decreasing the competition between and inside the plant which caused the development of leaf area [2]. In this regard, some reported the effect of planting pattern on the quantitative and qualitative yield of safflower [20], sunflower [21] and corn [2]. Proper planting pattern under suitable nutritional conditions causes the plant to reach the desired leaf area in less time and maximum vegetative and reproductive growth.

Table 2. Variance analysis of the effect of cultivation pattern and different levels of urea fertilizer on growth traits, yield, and yield components of Single Cross 704 corn

SOV	df	Mean square (MS)										
		Plant height	Stem diameter	LAI	First ear height from the ground	Ear diameter	Ear length	Number of row per ear	Number of seed per row	1000-seed weight	Seed yield	Fresh forage yield
Rep	2	690.7*	0.0033ns	1.27**	313.9**	0.31*	0.39ns	0.68ns	3.13ns	30.9ns	5942035.3**	274301744*
Planting patterns (PP)	1	10795.0**	0.31**	0.71*	113.3*	1.60**	19.0ns	0.91ns	140.5**	175.6ns	10556167.7ns	166466801ns
Error a	2	126.8	0.001	1.75	302.3	0.002	1.15	0.41	3.65	94.4	53398791.1	37776847
Urea (U)	3	1441.5**	0.018ns	1.77**	241.3**	0.54**	0.74ns	0.36ns	2.11ns	20.6ns	1352814.6**	991684629**
PP × U	3	104.3ns	0.001ns	0.10ns	3.08ns	0.23ns	6.16ns	2.68*	7.10*	19.2ns	8501924.5*	18530686ns
Error b	12	123.1	0.023	0.08	20.2	0.07	7.42	0.51	2.94	88.9	780048.9	41199596
CV (%)	-	5.28	7.78	7.70	4.34	4.57	9.39	5.10	11.30	13.01	22.52	10.71

*and **indicate a significant difference at the level of 5 and 1%, respectively, and ns shows no significant difference

Table 3. Comparison of the mean effect of planting pattern and different levels of urea fertilizer on growth parameters, yield, and yield components of Single Cross 704 corn

	Plant height (cm)	Stem diameter (cm)	LAI	First ear height from the ground (cm)	Ear diameter (cm)	Ear length (cm)	1000-seed weight (g)	Fresh forage yield (kg ha^{-1})
Planting patterns								
Single-row	188.5b	2.10a	3.55a	101.5b	6.30a	29.8a	69.7a	62540a
double-row	231.0a	1.87b	3.90a	105.8a	5.78b	28.1a	75.1a	57273a
Urea fertilizer (kg ha^{-1})								
Control	189.3c	2.04a	3.09d	96.1c	6.38a	28.8a	70.1a	44032d
120	207.7b	1.94a	3.53c	101.9b	6.15ab	29.4a	74.4a	56393c
240	216.3ab	1.93a	3.91b	105.3b	5.96bc	29.0a	71.8a	64932b
360	225.7a	2.02a	4.37a	111.3a	5.66c	28.6a	73.4a	74268a

The means with the same letters in each column are not statistically significant in terms of the comparison test of Duncan's multiply test at the 5% probability level.

Corn planting method is considered as one of the most important activities to achieve maximum yield. The results indicated that the arrangement of planting plants can affect their access to light, water, and nutrients [3]. The poor arrangement of the plants and the short distance between the plants on the row are considered as the main problems of the conventional planting pattern, which causes the competition between the plants to start earlier, which becomes more intense when the density of the plants increases per unit area. Further, double-row cultivation of corn is one of the proposed methods to solve the problems of the normal pattern, which results in reducing the competition and better use of environmental factors by the plant leading to an increase in crop yield due to better distribution of plants [4].

Based on the results, an increase in the average growth traits such as plant height and leaf area index was observed by increasing urea fertilizer, , which increased to 360 kg urea per hectare, leading to an increase of 16.12 and 29.2% in average plant height and leaf area index compared to the control treatment (Table 3). Some emphasized that the use of nitrogen led to an increase in leaf area in the plant and light penetration into the canopy, which resulted in increasing the rate of photosynthesis, product growth rate, leaf surface index, and yield [22]. The amount of soil nitrogen is one of the most important factors influencing the leaf area index of each plant and the development of canopy, which affects the size and longevity of the leaf, leading to an increase in leaf area index [22]. It seems that the gradual and continuous release of urea fertilizer due to application in different stages, along with the needs of the plant during the growing season increases the vegetative and reproductive growth of corn [23]. With the optimal use of nitrogen fertilizer, the growth rate of the leaves increases, the leaves complete their growth in less time than the non-consumption of nitrogen, and store the photosynthetic materials in excess of their needs in the stem, which are transferred to the seed after pollination. The results of the present study showed that stem diameter has a positive relationship with yield, which may be related to the re-transfer in grains, which can be important in filling the grains in the final stages of growth [9].

The 1000-seed weight is not significantly different under the treatment of planting pattern and urea fertilizer (Table 2). Lak et al. [3] and Shakermi and Rafiei [24] reported that the effect of planting pattern on the 1000-corn seed weight was not significant, although the cultivation pattern changed the number of seeds in a row. In addition, the grain weight is affected by the leaf area and the amount of photosynthetic production, although there was no significant difference between the treatments of the planting pattern since the experimental material is well-produced in the experimental area due to the presence of clear and sunny air and sufficient light [3]. On the other hand, the weight of 1000 seeds is more affected than the genotype if there are no adverse environmental conditions and optimal plant nutrition [14].

As shown in Table 3, the use of 360 kg of urea fertilizer per hectare led to the highest fresh forage yield so that fresh forage yield increased by 40.7% compared to the control treatment (no fertilizer consumption) . Some have linked an increase in growth parameters in maize to an increase in urea fertilizer consumption to enhance the activity of enzymes involved in photosynthetic reactions. [22].

In addition, the consumption of 360 kg of urea per hectare may increase the length of vegetative growth, as well as the foliage and forage of the plant yield. Fallah and Tadayon [25] reported that the maximum amount of forage produced per hectare was obtained with the highest amount of nitrogen consumed, which are in line with the results of the present study.

As shown in Table 2, the number of rows in ear and seeds per row, and the seed yield under interaction effect of planting pattern × urea fertilizer indicated a significant difference. Based on the results, the maximum number of rows was observed in ear in 120 kg urea application per hectare under the double-row planting pattern with an average of 15.22 rows, which increased by 7.29% compared to the control treatment. However, the minimum number of rows in ear was observed in lack of using nitrogen fertilizer under the single-row planting pattern with an average of 13.10 rows (Table 4). Hemmati et al. [22] reported that the interaction effect of planting pattern and urea fertilizer on growth characteristics such as plant height and leaf area, and yield components like the number of rows per ear, number of ear, and grain yield was significant, which is consistent with the results of the present study. Some researchers indicated that the number of rows in ear in the corn plant increased by increasing the urea fertilizer consumption, [8], which confirms the results of the present study. Furthermoe, the consumption of nitrogen fertilizer increased the surface area of the leaf and its durability. Thus, more asymmetries are provided to the plant for a longer period of time.

Single-row cultivation under 360 kg urea application per hectare resulted in the highest number of seeds per row and grain yield an average of 34.6 rows and 13784.6 kg ha^{-1}, respectively, which led to an increase of 13.5 and 37.4% compared to the control treatment (Table 4). Some researchers reported the highest grain yield per corn of single cross 704 cultivar at 300 to 400 kg urea per hectare [22, 26], which are consistent with the results of the present study.

The reason for the increase in grain yield under the use of nitrogen fertilizer conditions can be attributed to an increase in grain filling rate under the influence of high leaf nitrogen concentration during grain filling stage [27]. Based on the results, single-row cultivation was more efficient than double-row cultivation in terms of grain yield. It seems that there is a higher efficiency in single-row cultivation due to the more suitable distance and space for each plant to benefit from light and moisture absorption and fertilizer, as well as reducing competition within species and other factors, compared to double-row cultivation. Some reported that the volume of roots is higher due to having a wider space due to the suitable space for each plant in single-row cultivation, and the roots are developed at a higher level and depth and can use better than nutrients.

Table 4. Interaction effect of planting pattern in urea fertilizer on some quantitative and qualitative traits of Single Cross 704 corn

Urea fertilizer (kg ha^{-1})	Planting patterns	Number of row per ear	Number of seed per row	Seed yield (kg ha^{-1})	DMD (%)	ADF (%)	NDF (%)	ASH (%)
Control	Single-row	13.10c	29.9c	8624.7c	48.93abc	34.83c	44.70d	2.08bc
	double-row	14.11abc	28.1d	76354.1d	48.57bc	37.00a	52.70c	1.27d
120	Single-row	14.66ab	31.3bc	9715.5c	46.52c	33.82d	56.00b	2.00bc
	double-row	15.22a	31.1bc	8457.8c	50.80abc	33.66d	56.27b	2.43a
240	Single-row	13.44bc	32.7b	12835.1ab	49.80abc	29.32f	55.61b	2.19ab
	double-row	14.22abc	31.9b	10978.8b	51.73ab	35.95b	58.33a	1.80c
360	Single-row	14.33abc	34.6a	13784.6a	51.23ab	28.80f	56.18b	1.83c
	double-row	13.55bc	32.4b	12111.3ab	53.05a	31.42e	56.24b	1.50d

The means with the same letters in each column are not statistically significant in terms of the comparison test of Duncan's multiply test at 5% probability level.

Qualitative traits

The results showed that the planting pattern had a significant effect on the nitrogen percentage of aerial and seed parts. Further, the effect of urea fertilizer on the nitrogen percentage of aerial, seeds, and soil was significant (Table 5). As shown in Table 6, single-row cultivation increased the amount of nitrogen in the aerial parts, but double-row cultivation led to an increase in the grain nitrogen. The rate of increase in aerial organ nitrogen in the single-row cultivation system was 7.18% and the rate of decrease in seed nitrogen percentage in this cultivation system was 9.04%. Based on the results, a significant increase was observed in the percentage of seed, aerial, and soil nitrogen after harvest by increasing urea fertilizer levels. Further, the highest average percentage of nitrogen in the aerial organs (1.89%), seeds (2.05%), and soil (0.13%) was observed in 360 kg of urea per hectare (Table 6). Further, the percentage increase in nitrogen uptake in aerial organs, seeds, and soil was 35.9, 16.5, and 24.61%, respectively, compared to the control treatment. Increasing the content of nitrogen absorbed in different organs of the plant results in increasing grain yield due to increased leaf chlorophyll [9]. The results are consistent with those of another study in which the total amount of nitrogen absorbed by the canola plant increased by increasing nitrogen fertilizer consumption, [28], which is in line with those of the present study.

The qualitative traits of forage showed a significant difference under urea fertilizer and planting patterns treatments. As shown in Table 5, the interaction of urea × planting pattern on DMD, ADF, NDF, and ASH traits was significant at 1% probability level (Table 5). The highest amount of digestible dry matter (DMD) was obtained in double-row cultivation and the application of 360 kg of urea per hectare with an average of 53.05%, which increased by 8.55% compared to the control treatment (Table 4). In this regard, other researchers reported the significant effect of nitrogen fertilizer and various cultivation systems on the quality traits of corn forage including DMD, and emphasized that the highest content of this trait was observed in treatments of 240 and 360 kgha^{-1} [29]. In addition, Al-Madras et al. [30] reported that DMD increased by increasing the urea fertilizer, which is consistent with the results of the present study.

The highest mean was observed in the amount of crude protein in single-row cultivation (M=19.27%) and the application of 360 kg of urea fertilizer per hectare (M=20.80%) (Table 6). Saber et al. [31] reported that urea fertilizer increased uptake by accelerating the activity of reductar nitrate enzyme and increased protein in spinach. It seems that nitrogen is one of the main structures of amino acids and its higher consumption causes an increase in the percentage of crude protein in forage [11]. The changes in plant protein are direct and linear to nitrogen fertilizer values, which indicates that high levels of urea fertilizer increase photosynthetic pigmentation and leaf surface durability, which results in increasing the amount of protein in young and juicy leaves [25]. Some showed that increasing nitrogen consumption, along with its benefits to the plant, increased plant growth and protein concentration, and accordingly forage and protein yield was achieved by consuming 320 kg of nitrogen per hectare [25] which is in line with the results of the present study in which single-row cultivation led to an increase in crude protein compared to two-row cultivation. In this regard, a decrease in the percentage of raw protein by increasing plant density may be related to competition between plants for nitrogen [32]. On the other hand, some researchers reported that increasing the density significantly led to a reduction of the percentage of crude protein in the whole corn plant, as high shade and density accounted for the amount of nitrate reductase enzyme, as an important enzyme in converting nitrate nitrogen to nitrite in the amino acid synthesis cycle, which decreases the percentage of crude protein in the whole corn plant, which may be reduced [33].

Acid detergent fiber (ADF) insoluble fiber, i.e. cellulose-free cell wall which represents digestibility, is considered as an important feature in assessing forage quality [34]. Non-application of urea fertilizer under two-row cultivation conditions had the highest ADF (M=37.0%) and the lowest average of this feature was observed in the application of 240 and 360 kg of urea fertilizer per hectare under single-row cultivation conditions with an average of 29.32 and 28.80%, respectively (Table 4). Nitrogen is one of the most important nutrients affecting the yield and quality of crops including corn since it is considered as an important component of organic compounds such as enzymes, proteins, and chlorophyll. The effect of nitrogen on forage yield was confirmed by some other studies [32].

Other qualitative traits of forage include the amount of insoluble fiber in neutral detergent (NDF), i.e. the cell wall, which indicates the potential for forage consumption by livestock [34]. The highest NDF average was observed in the application of 240 kg of urea fertilizer per hectare under double-row cultivation conditions (M=58.33%), which had an increase of 9.65% compared to the control group. The lowest mean was related to the control treatment in single-row cultivation (M=44.70%) (Table 4). Soluble fiber in neutral detergents includes total lignin, cellulose, and hemicellulose, which is a measure of cell wall volume. An increase in the age of the plant results in decreasing its ability to digest dry matter and proteinand increasing raw fiber and lignin [34]. Baghdadi et al. [29] showed that nitrogen treatment of 240 kg ha^{-1} is the best treatment for this trait, which is consistent with those of the present study.

Ash (minerals) is another factor affecting the quality of forage [35] in which the application of 240 kg of urea fertilizer per hectare under double-row cultivation conditions led to the creation of the highest average ASH with an average of 2.43%. Compared to the control treatment, the control had an increase of 47.7%. The lowest average of this trait was related to the non-application of urea fertilizer under double-row cultivation conditions with an average of 1.27% (Table 4). In another study conducted on the corn plant, the consumption of nitrogen fertilizer increased the ash content [36], which is in line with the results of the present study. The total amount of ash increased by increasing nitrogen application in some studies conducted on the yield and quality of corn forage under the influence of different amounts of nitrogen fertilizer [37, 38].

Table 5. Variation analysis of the effect of planting pattern and different levels of urea fertilizer on the quality of Single Cross 704 corn

SOV	df	Mean square (MS)									
		Shoot nitrogen percentage	**Seed nitrogen percentage**	**Soil nitrogen percentage after harvest**	**DMD**	**CP**	**WSC**	**CF**	**ADF**	**NDF**	**ASH**
Rep	2	0.43**	0.007ns	0.0008**	200.5**	28.57**	26.60**	265.4**	87.6**	237.6**	0.28**
Planting patterns (PP)	1	0.084*	0.20**	0.00001ns	22.06**	3.50*	1.20ns	0.94ns	47.52**	45.7**	0.45**
Error a	2	0.012	0.10	0.0008	33.28	3.8	0.004	0.003	0.16	0.15	0.001
Urea (U)	3	0.56**	0.15**	0.001**	16.98**	15.72**	11.15*	3.57**	34.97**	90.6**	0.42**
PP × U	3	0.015ns	0.002ns	0.00007ns	5.38**	1.16ns	0.13ns	0.92ns	11.94**	20.47**	0.39**
Error b	12	0.0093	0.013	0.00006	0.31	0.39	2.73	0.41	0.07	0.18	0.028
CV (%)	-	5.97	6.08	6.99	1.12	3.33	9.07	1.11	0.84	0.78	8.95

* and ** indicate a significant difference at 5 and 1% significance levl and ns: no significant difference

Table 6. Comparison of the effect of planting pattern and different levels of urea fertilizer on some quality traits of Single Cross 704 corn.

	Shoot nitrogen percentage	**Seed nitrogen percentage**	**Soil nitrogen percentage after harvest**	**CP (%)**	**WSC (%)**	**CF (%)**
Planting patterns						
Single-row	1.67a	1.81b	0.11a	19.27a	18.45a	57.37b
double-row	1.55b	1.99a	0.11a	18.51b	18.00b	57.77a
Urea fertilizer (kg ha^{-1})						
Control	1.21c	1.71b	0.098d	17.06d	19.80a	58.03a
120	1.55b	1.83b	0.11c	18.21c	17.95ab	56.93b
240	1.80a	2.02a	0.12b	19.51b	16.53b	58.42a
360	1.89a	2.05a	0.13a	20.80a	18.62ab	56.91b

The means with the same letters in each column are not statistically significant in terms of the comparison test of Duncan's multiply test at the 5% probability level.

Simple correlation between traits and stepwise regression analysis

Table 7 indicates the results of the simple correlation between quantitative and qualitative traits. As shown, DMD, CP, and NDF traits were positively and significantly correlated to grain yield with plant height traits, leaf surface index, height of the first ear above ground, fresh forage yield, percentage of aerial, seed, and soil nitrogen, while WSC, CF, and ADF showed a negative and significant correlation with ear diameter and the number of rows in ear. In fact, increasing the ear length due to an increase in the consumption of urea fertilizer results in increases the number of grains in the ear row, which leads to an increase in the number of grains in the ear and the weight of grain yield. Some reported similar results in maize [8, 39]. The content of CP in the forage and NDF led to an increase in plant height, leaf area index, ear height above ground, grain yield, fresh forage yield, percentage of aerial, seed, and soil, while WSC, CF, and ADF showed a negative and significant correlation with ear diameter and the number of rows in ear.

Table 8 shows the results of stepwise regression analysis in which grain yield was considered as a dependent variable and other growth and yield characteristics as independent traits. As shown, the regression model was significant and a total of 78.54% of the grain yield changes could be justified with stem diameter, leaf surface index, ear length, and 1000-seed weight.

The present study aimed to evalaute the effect of planting pattern and different levels of nitrogen fertilizer (urea) on some quantitative and qualitative traits of Single Cross 704 corn. The results showed the significant effect of nitrogen fertilizer and planting pattern on growth and yield parameters (plant height, leaf surface index, first ear height from the ground, ear diameter), quality (aerial and seed nitrogen percentage), and forage quality. Also, the interaction of nitrogen fertilizer in planting pattern on the number of rows in ear, the number of seeds per row, grain yield, DMD, ADF, NDF and ASH was significant. Better results were observed in double-row cultivation in growth and morphological traits, and single-row cultivation on yield traits and yield components. In the case of forage quality traits, double-row cultivation had more satisfactory results compared to single-row cultivation. The use of urea fertilizer increased the growth and yield parameters and improved the quality characteristics of corn forage. The results of stepwise regression analysis showed that stem diameter, leaf surface index, ear length, and 1000-seed weight in total could justify 78.74% of the grain yield changes. In general, single-row cultivation for seed production and double-row cultivation for fresh forage production had better results under the application of 360 kg urea per hectare in Varamin region, which can be recommended to farmers in the region.

Table 7. Simple correlation between quantitative and qualitative traits of Single Cross 704 corn under treatment of urea fertilizer and planting pattern

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2	-0.7																			
3	0.82	-0.2																		
4	0.83	-0.21	0.99																	
5	-0.96	0.46	-0.94	-0.94																
6	-0.73	0.64	-0.39	-0.39	0.66															
7	-0.09	-0.35	-0.56	-0.53	0.25	-0.45														
8	-0.62	0.91	-0.1	-0.1	0.42	0.85	-0.54													
9	0.84	-0.77	0.52	0.56	-0.71	-0.55	0.21	-0.59												
10	0.55	0.17	0.93	0.92	-0.75	-0.11	-0.75	0.25	0.2											
11	0.53	0.14	0.91	0.9	-0.71	0.02	-0.82	0.3	0.23	0.98										
12	0.53	0.06	0.88	0.87	-0.68	0.06	-0.87	0.26	0.24	0.94	0.98									
13	0.89	-0.42	0.95	0.94	-0.94	-0.49	-0.51	-0.33	0.56	0.81	0.8	0.82								
14	0.64	-0.01	0.94	0.94	-0.8	-0.14	-0.72	0.13	0.34	0.96	0.96	0.95	0.87							
15	0.84	-0.27	0.93	0.91	-0.94	-0.64	-0.37	-0.32	0.44	0.82	0.74	0.7	0.93	0.82						
16	0.50	0.2	0.9	0.89	-0.69	-0.01	-0.82	0.31	0.16	0.99	0.99	0.97	0.79	0.96	0.77					
17	-0.48	0.49	-0.47	-0.45	0.4	-0.06	0.61	0.2	-0.33	-0.36	-0.48	-0.63	-0.64	-0.48	-0.32	-0.41				
18	-0.08	-0.3	-0.27	-0.33	0.19	-0.23	0.07	-0.47	-0.35	-0.33	-0.37	-0.26	-0.01	-0.31	-0.02	-0.33	-0.27			
19	-0.27	-0.43	-0.76	-0.76	0.49	-0.24	0.85	-0.57	-0.01	-0.93	-0.95	-0.91	-0.59	-0.87	-0.57	-0.96	0.29	0.48		
20	0.78	-0.47	0.8	0.81	-0.76	-0.14	-0.51	-0.16	0.73	0.64	0.73	0.79	0.82	0.75	0.59	0.66	-0.77	-0.31	-0.55	
21	-0.24	-0.03	-0.2	-0.19	0.34	0.73	-0.34	0.35	0.05	-0.17	0.02	0.15	-0.18	-0.07	-0.51	-0.06	-0.53	-0.18	-0.07	0.35

1: plant height, 2: stem diameter, 3: LAI, 4: Ear height from the ground, 5: ear diameter, 6: ear length, 7: number of row per ear, 8: number of seed per row, 9: 1000-seed weight, 10: seed yield, 11: fresh forage yield, 12: shoot nitrogen percentage, seed nitrogen percentage, soil nitrogen percentage after harvest, 15: DMD, 16: CP, 17: WSC, 18: CF, 19: ADF, 20: NDF, and 21: ASH

-1	-0.9	-0.8	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1

Negative correlation ← non-correlation → positive correlation

Table 8. Stepwise regression for grain yield as a dependent variable and other traits as an independent variable

Term	Coef	SE Coef	T-Value	P-Value
Constant	-13176	669	-19.68	0.032
Stem diameter (X1)	476.1	68.2	6.98	0.0091
LAI (X2)	0.26918	0.00786	34.24	0.019
Ear length (X3)	-2796.3	33.6	-83.26	0.008
1000-seed weight (X4)	729.0	63.0	11.58	0.055
R-Sq(adj)= 78.54%				
Y= -13176 + 476.1 (X1) + 0.26918 (X2) + 729.0 (X3) – 2796.3 (X4)				

Conflict of interests

The authors declare that there are no conflicts of interest related to this article.

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