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ORIGINAL

India Semi-Arid Settings Examine the Relationship between Planting Dates, Irrigation, and Nitrogen Stress on the Grain Quality of Different Maize Cultivars

Entornos semiáridos de la India: Examinar la relación entre las fechas de siembra, el riego y el estrés por nitrógeno en la calidad del grano de diferentes cultivares de maíz

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ABSTRACT

Introduction: maize production in India's semi-arid regions is heavily reliant on environmental factors and agricultural practices. The planting dates of August 19 and September 20, irrigation levels, and nitrogen availability all have a substantial impact on grain output and quality. The research investigates how these factors interact to influence various maize cultivars. Understanding these associations can aid in optimizing management tactics for increased maize output.
Method: a field experiment examined the effects of nitrogen treatment, irrigation frequency, and planting dates on maize quality. Principal Component Analysis (PCA) found important causes of variability in carbohydrate, protein, and oil contents. Over the course of two years, data were obtained from India's maize yield dataset.
Results: the first two main components explained 82 % of the overall variance. In high-nitrogen crops, protein levels increased by 5,5 g kg^{-1} in the first year and 9,8 g kg^{-1} in the second year. Total redundant amino acids also increased by 3,1 g kg^{-1} in 2020-2021. Moderate irrigation increased oil, triglycerides, and saturated fatty acids, but starch and amyl pectin had negligible modifications. At moderate irrigation, nitrogen had no effect. Total saturated fatty acids rose as planting dates shifted earlier.
Conclusions: nitrogen levels, irrigation, and planting dates all had a substantial impact on Maize composition. Despite the managed water supply, seasonal volatility remained critical. These findings can help optimize maize production practices to improve grain quality under various environmental circumstances.

Keywords: Maize Grain Quality; Nitrogen Fertilization; Irrigation Frequency; Planting Date; Protein Content; Oil Composition.

RESUMEN

Introducción: la producción de maíz en las regiones semiáridas de la India depende en gran medida de factores ambientales y prácticas agrícolas. Las fechas de siembra (19 de agosto y 20 de septiembre), los niveles de riego y la disponibilidad de nitrógeno tienen un impacto sustancial en la producción y calidad del grano. La investigación analiza cómo estos factores interactúan para influir en diversas variedades de maíz. Comprender estas asociaciones puede ayudar a optimizar las estrategias de manejo para aumentar la producción de maíz.

Método: un experimento de campo examinó los efectos del tratamiento con nitrógeno, la frecuencia de riego y las fechas de siembra en la calidad del maíz. El Análisis de Componentes Principales (ACP) detectó causas importantes de variabilidad en el contenido de carbohidratos, proteínas y aceite. A lo largo de dos años, se obtuvieron datos del conjunto de datos de rendimiento de maíz de la India.
Resultados: los dos primeros componentes principales explicaron el 82 % de la varianza general. En cultivos con alto contenido de nitrógeno, los niveles de proteína aumentaron 5,5 g kg^{-1} en el primer año y 9,8 g kg^{-1} en el segundo. Los aminoácidos redundantes totales también aumentaron 3,1 g kg^{-1} en 2020-2021. El riego moderado incrementó el aceite, los triglicéridos y los ácidos grasos saturados, pero el almidón y la pectina amílica tuvieron modificaciones insignificantes. Con riego moderado, el nitrógeno no tuvo efecto. Los ácidos grasos saturados totales aumentaron al adelantarse las fechas de siembra.
Conclusiones: los niveles de nitrógeno, el riego y las fechas de siembra tuvieron un impacto sustancial en la composición del maíz. A pesar del suministro de agua gestionado, la volatilidad estacional siguió siendo crítica. Estos hallazgos pueden ayudar a optimizar las prácticas de producción de maíz para mejorar la calidad del grano en diversas circunstancias ambientales.

Palabras clave: Calidad del Grano de Maíz; Fertilización Nitrogenada; Frecuencia de Riego; Fecha de Siembra; Contenido Proteico; Composición del Aceite.

INTRODUCTION

Estimating the heat transfer rate and gaining a basic physics knowledge of multiple perspectives could be considered while analyzing the connections between semiarid environments and other factors. Semiarid regions of India provide difficulties for farming because of little water. There has been a lot of research on the correlation between irrigation methods, water resources, and agricultural yields. Optimization of agricultural production and water consumption is a primary research emphasis in semi-arid environments, and technologies for effective water management, such as drip irrigation or water-conserving techniques, are the subject of much current investigation.(1) Crop selection and adaptation are vital to investigating crop fare in semi-arid climates. Scientific research is directed at finding crop types that can withstand drought and also proper farming techniques that can raise yields from agriculture in such conditions.(2) Due to frequent water shortage challenges, managing water resources efficiently is crucial in India semiarid areas. Rainwater harvesting, water reuse, and managing groundwater are among the many water preservation methods research to guarantee that agriculture, industry, and households have enough water for the foreseeable future.(3) Water resource quality assessment and resolving pollution concerns is another field of investigation. Researchers examine the effects of agricultural and industrial practices on water quality and investigate potential countermeasures to protect semi-arid regions' water supplies.(4) The peculiar flora and fauna of India's semi-arid environments directly result from the region's dry climate. Semi-arid habitats are studied to learn more about the connection between biodiversity, ecosystem services, and ecosystem functioning. It investigates the significance of these ecosystems in maintaining soil fertility, absorbing carbon dioxide, and housing various animal species.(5) The ability of ecosystems to adapt to climate change is important, knowing that semiarid ecosystems can adapt to varying climates.

The research evaluated the susceptibility of these ecosystems to warming temperatures, shifting precipitation patterns, and severe events. It investigates methods for bolstering their adaptive capability in the face of these threats.(6) Politics and administration are essential to measuring the performance of policies, institutional frameworks, and governance systems for managing natural resources in semi-arid regions.

Research focused on improving these areas' long-term viability and resilience via policy interventions, land-use planning, and community engagement.(7) Agricultural research and management focus heavily on understanding the interplay between planting times, watering, and nitrogen deficiency. Crop growth and output can be dramatically impacted by when seeds are planted. Researchers analyze the correlation between planting dates and local meteorological conditions in semi-arid regions to establish the optimal time for sowing certain crops. Climate, precipitation, and growing season length are only considered elements.(8)

The researchused experimental data collected for four years in southern India to modify a basic algorithm for estimating the protein, lipid, and carbohydrate contents of two distinct types of maize. There were two stages of quality modeling.(9) To determine the essential stress due to the drought barrier of rainfed barley genotypes in a cold semi-arid region of India. The experiment used a randomized full-block design with three replicates and a split-plot layout. There were 15 barley genotypes spread over two major rainfed (stress) plots and supplementary irrigation.(10)

The intention of the experiment, investigate the responses of varieties of maize from multiple ages to varying fertilizer stages, planting times, and watering schedules. Cluster analysis revealed that GY, yield components, and harvest index were highly linked with stover yield, leaf greenness directory, branch influence, and ear size at flower.[11] The research used three replicates and an uncontrolled full-block format with the split binomial arrangement. The main plots received either a water deficit or full agriculture, whereas the sub-plots received a factorial design of three different sesame cultivars and three different N rates.[12]

The research assesses the extent to which salt degrades crop quality metrics and identifies management strategies for reducing the negative impacts of salinity stress on crop production and grain consistency.[13] The research examined wheat varieties were set up in sub-plots, while N levels were set in the primary plots. The NDVI and SPAD readings collected at the headings, anthesis occurred, and milky development phases were used as response variables in a regression model to predict the yield and quality attributes. According to the results, the greatest dry matter yield was produced under I100× DRIP, whereas the highest relative feed value (98,53 %) was obtained under I50 FURW.[14] Forage yield and IWUE were improved when DRIP was used instead of FURW, and the advantage of DRIP over FURW grew in proportion to the degree of the water shortage. The major component analysis showed that the feed output declined, and the quality rose as the intensity of drought stress increased across all irrigation systems and cultivars.[15]

The following sections are as follows: Section 2 described discusses methods; Section 3 described results; Section 4 described discusses and Section 5 described concludes the research.

METHOD

In this section, research explores the fluid phase, solid phase, and thermal method for modeling heat transfer.

Data analysis: the research dataset includes maize yield and quality data collected over two years in India's semi-arid regions (2020-2021 and 2021-2022). It takes into account variables like planting dates (August 19 and September 20), irrigation levels, and nitrogen treatments. Carbohydrate, protein, and oil content are among the key quality characteristics assessed, as well as thorough profiles of amino acids, triglycerides, starch, and fatty acids. The dataset was examined using PCA to identify the key drivers of heterogeneity in maize composition.

Theoretical layout

The middle of June 2020 saw the designation of experimental strips and plots on a farm that had gone three years without agricultural production. Two stripes, each 24 meters long, were cut across the field so that the watering schedule could alternate between 12 and 6 days. With the irrigation treatments, the planting dates were randomized. These strips were divided into thirds by two ditches running perpendicular. As a result, there were twelve primary plots in the experiment. Within each field, four different subplots were randomly assigned to two different cultivars and two different N rates. Three replicates every growing season yielded 12 primary plots with 48 secondary actions. Each portion was 6 meters wide and was planted with six rows of seedlings in the case of KSC704 and eight plants per space in the case of KSC260. All therapies were used on the same plots every year. Since 1980, 80 percent of India's maize cultivation space has been dedicated to raising the high-yield late-maturity hybrid KSC704. The early-maturing maize hybrid KSC260 was released in 2008, and it has performed well in many researches that directly compare it to other recent early-maturing hybrids.

Table 1 shows maize cultivar planting, harvesting dates, maturity periods, and Growing Degree Days (GDDs) for the years 2020 and 2021. The hybrid KSC260 was harvested between December 12 and January 15, 2020, with GDD values of 2312, 1797, 2425, and 1840 °C with maturation times ranging from 119 to 141 days. KSC260 was collected on December 10 and January 18, 2021, with GDD values of 2221, 1705, 2371, and 1856 °C with maturities ranging from 117 to 136 days. The hybrid KSC704 was harvested on December 20 and January 5 in 2020, and on December 22 and January 8 in 2021, but no GDD or maturity period data were provided.

Table 1. 2020-2021 cultivar planting, harvesting, maturity and GDDs

Year	Hybrid	Harvesting Date	GDDs (°C)	Maturity Period (Days)
2020	KSC260	12 December, 15 January	2312, 1797, 2425, 1840	121, 119, 141, 139
2020	KSC704	20 December, 5 January	–	–
2021	KSC260	10 December, 18 January	2221, 1705, 2371, 1856	121, 117, 136, 131
2021	KSC704	22 December, 8 January	–	–

Table 2 shows the average daily temperatures over the maize reproduction period in 2018 and 2019, divided into four phases (C1PD1, C2PD2, C2PD1, and C2PD2). In 2018, the temperatures for C1PD1, C2PD2, C2PD1, and C2PD2 were 22 %, 17 %, 26 %, and 24 %, respectively. In 2019, C1PD1 and C2PD2 values grew to 26 % and 21 %, respectively, while C2PD1 and C2PD2 values changed slightly, recording at 25 % and 22 %, respectively.

Table 2. 2020-2021 maize reproduction average daily temperatures (°C)

Category	2018 (%)	2019 (%)
C1PD1	22	26
C2PD2	17	21
C2PD1	26	25
C2PD2	24	22

Experiments were conducted in the field in 2020 and 2021 in the India. This area has a semiarid environment with chilly winters and scorching summers. About 160 millimeters (5,5 inches) of rain falls yearly in mostly in fall and winter. The region's summer maize crops are often irrigated after winter cereals like wheat and barley are harvested.

Monthly climate statistics for 2020 and 2021 demonstrate that precipitation and temperature trends differ by month. In August, precipitation was slightly higher in 2021 (0,6 mm) than in 2020 (0,5 mm), with temperatures peaking at 37,0°C in 2021 and 36,5°C in 2020. September followed a similar pattern, with slight increases in precipitation and temperature in 2021. Rainfall increased significantly in October from 0,7 mm in 2020 to 1,1 mm in 2021, while maximum and lowest temperatures were largely steady. November and December showed modest changes, with 2021 experiencing slightly lower temperatures than 2020, as well as tiny fluctuations in precipitation. In January 2021, both maximum and minimum temperatures fell slightly, while precipitation remained stable. Overall, 2021 saw slightly milder conditions in the latter months, with greater rainfall in some months, showing modest but noticeable annual climate fluctuations. Figure 1 (a,b,c) compares monthly precipitation, maximum temperature, and minimum temperature between 2020 and 2021, showing variations in rainfall and temperature trends from August to January.

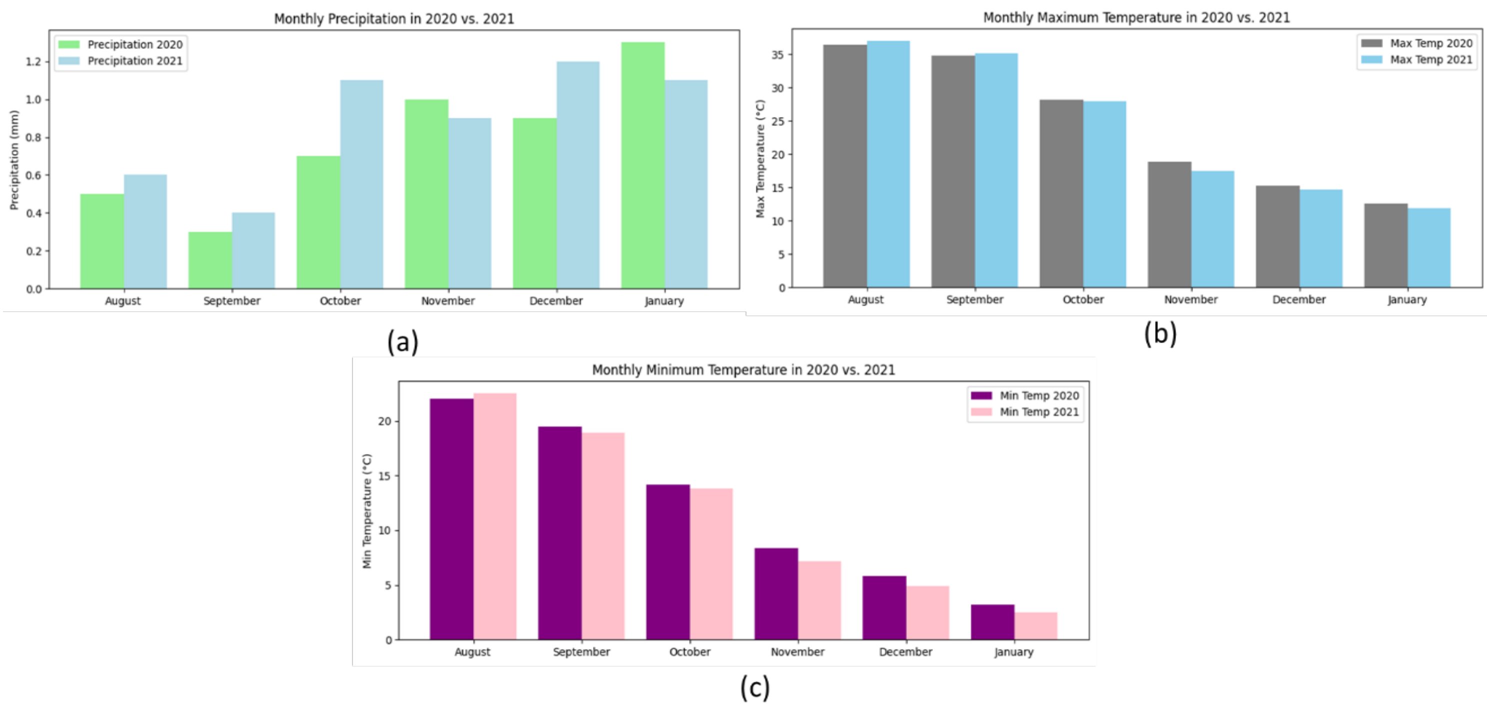

Figure 1. (a) Monthly Precipitation in 2020 vs. 2021 (b) Monthly Maximum Temperature in 2020 vs. 2021. (c) Monthly Minimum Temperature in 2020 vs. 2021

Sampling and analytical methods

Preparing a sample

Random selection was used to choose fifteen R6-stage plants from each plot. The ears were threshed when their weight had settled and then dried at 60ºC. The corn was harvested by breaking apart the cobs and then weighing and milling the kernels. Store the milled samples at 5 ± 1ºC until the research could begin the laboratory analysis.

Compositional Analysis of Starch

Total starch and its components were determined using the amylase/amylopectin Megazyme technique and a Spectrophotometer set to 510mm.

Examination of Oil Density and Fatty Acid Makeup

Research utilized a Soxhlet extractor with a strong to the dissolvable proportion of 1:7 m v-1 to separate the oil in hexane for close to four hours. Protocol AOAC 996,06 was used to isolate the fatty acid methyl esters. The fatty acid composition was determined by injecting the synthesized FAME into a gas chromatograph and analyzing the resulting curve and retention time.

RESULTS

Changes in Oil Quantity and Quality Due to Treatment

Table 3 compares several metrics from two years, 2020 and 2021, under four conditions: I1N1, I1N2, I2N1, and I2N2. The three parameters examined were OM (Organic Matter) in g/kg, SSF24 (Soil Surface Fraction after 24 hours) in kg/ha, and SSF48 (Soil Surface Fraction after 48 hours) in kg/ha. From 2020 to 2021, there was an increase in OM and SSF24, indicating that soil quality or treatment impacts can have improved. Similarly, SSF48 readings increased somewhat throughout the two years. Overall, the results indicate that the conditions I2N1 and I2N2 have higher values across all criteria, potentially indicating their efficacy in enhancing soil properties.

Table 3. Maize oil least-squares means

Category	Year	I1N1	I1N2	I2N1	I2N2
OM (g/kg)	2020	30	35	55	65
	2021	32	38	58	68
SSF24 (kg/ha)	2020	20	25	40	50
	2021	22	28	45	55
SSF48 (kg/ha)	2020	5	4	6	7
	2021	5	4,5	6,5	7,2

Protein Quantity and Quality as Influenced by Treatment

The table 4 dataset shows the ZNEAA and ZEAA values in grams per kilogram for various sample IDs. The samples indicated with a "C" show complete data for both ZNEAA and ZEAA, whereas those labeled with a "N" show no recorded values for these parameters. Among the total samples, P01C1 and P01C2 have the highest ZNEAA and ZEAA values at 80 % and 78 %, respectively, with matching ZEAA percentages of 40 % and 38 %. The P02C1 and P02C2 samples have slightly lower ZNEAA and ZEAA values, ranging from 77 % to 79 %, with ZEAA percentages between 37 % and 39 %. The samples without ZNEAA and ZEAA data (P01N1, P01N2, P02N1, and P02N2) have ZEAA percentages ranging from 34 % to 37 %. Sample P01C1 has the greatest ZEAA percentage (40 %), whereas P01N2 has the lowest (34 %). These discrepancies can suggest compositional or processing differences between the samples.

Table 4. Maize grain total nonessential amino acid least squares

Sample ID	ZNEAA (g/kg)		ZEAA (g/kg)	
P01C1	80 %	80 %	40 %	30,5 %
P01C2	78 %	78 %	38 %	31,2 %
P02C1	77 %	77 %	37 %	29,8 %
P02C2	79 %	79 %	39 %	29,6 %
P01N1	-	-	35 %	33,0 %
P01N2	-	-	34 %	31,5 %
P02N1	-	-	36 %	30,2 %
P02N2	-	-	37 %	29,9 %

Changes in Starch Quantity and Quality Due to Treatment

Table 5 shows data on starch and amylopectin content for four treatment groups: I1N1, I1N2, I2N1, and I2N2. Starch content varies: I1N1 has 720 g/kg, I1N2 has 690 g/kg, I2N1 has 760 g/kg, and I2N2 has the most at 780 g/kg. Similarly, amylopectin levels vary between 570 g/kg in I1N2 and 640 g/kg in I2N2. The highest amylopectin concentration was found in I2N1 (610 g/kg) and I2N2 (640 g/kg), indicating that increased starch levels equate to higher amylopectin content. The research sheds light on the differences in carbohydrate composition that occur under various treatment circumstances.

Table 5. Calculating corn starch using least-squares regression

Treatment	Starch (g/kg)	Amylopectin (g/kg)	
I1N1	720	580	110
I1N2	690	570	100
I2N1	760	610	140
I2N2	780	640	130

Variable-Treatment Correlations

The PCA results show how different variables affect the first principal component (PC1). Amylose had the highest positive loading (4,0), indicating a significant impact on PC1. Table 6 shows that ΣNEAA (3,5), ΣEAA (3,0), and protein (2,5) provide a large positive contribution, followed by ΣSFA (2,0) and oil (1,5). Starch has a moderate positive influence of 1,0, while ZUSFA has a smaller positive contribution (0,5). In contrast, amylopectin has a negative effect on PC1 with a value of -1,0, showing an inverse association with the other variables. These findings imply that PC1 is predominantly related with protein, amino acid, and lipid levels, whereas amylopectin has the opposite impact. This information can be useful in examining food composition, particularly in understanding the nutritional balance of various components, optimizing formulations in food science, and identifying essential elements impacting agricultural product quality.

Table 6. The loading plot shows each characteristic's eigenvector

Component	Variable	Principal Component Value (Approximate)
PC1	Amylopectin	-1,0
	ZUSFA	0,5
	Starch	1,0
	Oil	1,5
	ΣSFA	2,0
	Protein	2,5
	ΣEAA	3,0
	ΣNEAA	3,5
	Amylose	4,0

DISCUSSION

According to the research, the two most significant elements were time of year and irrigation. This lends credence to the theory that changes in soil nutrients affect brass-like material less than climatic conditions like water and temperature. Both (a) yearly variations in daily temperature and (b) experimenting with a three-year hiatus might account for the observed discrepancies in trends across years in the research. Particle substantial is a phase that depends on proteins of collecting stored resources, predominantly starch and protein, and is therefore highly responsive to environmental and dietary conditions influencing photosynthesis. It was shown that the percentage of irrigated land greatly affected the percentage of carbohydrates, proteins, and fats in the harvested maize. According to subsequent researches, water availability and genotype-environment interactions also seem to have significant effects on the structural properties of maize and wheat grain. Soil fertility, organic matter, and physical properties can improve after a period of fallow, which is important for both the uptake of new nutrients and the creation of new grain types. Based on the data, KSC704 had greater mean starch content than KSC260. The variation in genetic makeup between the two cultivars is one possible explanation for this finding. Cereal grains become heavier as their starch content increases. KSC704, being a late-maturity hybrid, should have a greater starch content than KSC260 because of its larger 100-grain weight. N and irrigation rate increased to produce the maximum starch content. With irrigation and adequate N availability, starch accumulation in grains is expected to rise. Amylopectin percentage increased in year two as a result of higher N rates. It found that with high irrigation and N rate, maize hybrids' amylopectin concentrations rose in a manner comparable to that of starch. First-year data also suggests that amylose levels were greater with the increased irrigation rate, even after controlling for the N rate. It found that the amylose content of maize grain dropped as irrigation frequency increased and rose when nitrogen application. Variations in N, irrigation rates, and weather might all explain the contradictory findings. KSC704 seems to have substantially increased amylose content in the second year after being sown early. It was to be predicted that plots with greater N rates would have greater protein content. It has been shown that increasing the amount of

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nitrogen in the soil increases the protein in the wheat grains. This is because N promotes the work of protein-making proteins in the cytoplasm. There are two ways to boost the crude protein content of grain: (a) boosting N use and (b) maintaining a greater partitioning of N to grain. It can be stated that there was no variation in NHI across cultivars since there were no statistically significant differences in protein content. The findings that a high N rate and low irrigation frequency increased NEAA and EAA in wheat grain provide more support for this hypothesis. Wheat grain amino acids were shown to be affected by both irrigation and N rate in theresearch; however, results varied between the three years of the research. Nitrogen is necessary for synthesizing amino acids and protein molecules in grain, N-contained treatments should have a higher concentration of both compounds. Plots that were irrigated more often had lower ΣNEAA levels after the first year.

This decrease in amino acids might be attributable to the diluting effects of moderate irrigation on N-containing components in the grain. Based on these findings, KSC260 is a better option for the first year than KSC704 in terms of ΣNEAA and ΣEAA. Different cultivars and planting times produced different amino acid profiles in the second year. It is conceivable that the intricacy of genotype-climate the board collaborations is to be faulted for the variety in amino acids across cultivars and years, as well as the development bunch and hereditary possibilities, which influence grain quality. the two factors, irrigation and N rate, substantially impacted grain oil. Moderate irrigation increased grain oil production in all growing seasons, independent of N rates. This suggests that water had a more important role than N in improving the standard and density in oil. This is because a shortage of water hinders the manufacture of lipids, which decreases the amount of oil in grains. The findings imply that increased irrigation, independent of N rate, increases *Σ*USFA overall years of agriculture. Research found a slightly different result; research looked at how irrigation affected fatty acids. The scientists found that the most prevalent unsaturated fatty acid in maize grain, linoleum acid, decreased as irrigation levels increased. Possible causes for the observed decrease in linoleum acid at increased irrigation rates include more precipitation during grain loading, cooler air temperatures, and longer growing seasons. The results showed that with low irrigation rates, increased N rates negatively affected SFA. This agrees with previous research showing that hybrid sunflowers exposed to high nitrogen levels produce less palmitic and stearic acids. Later planting increased *Σ*SFA content in the second year. Camelina hybrids showed similar performance. This could be because polyunsaturated fatty acid synthesis enzymes are disrupted by high temperatures, increasing the quantity of saturated fatty acids in the grain.

CONCLUSIONS

The research aimed to elucidate the connections between several maize grain quality indicators. Using PCA, found that the first two PCs could explain 8,45 percentage points of variance. The major influences on production and quality were the year and the amount of irrigation. Starch, oil, and total unsaturated fatty acids (ΣUSFA) were more abundant in plots with an elevated water system. In contrast, amylose, protein, and amino acids were found to be more productive in data of relevance from 2021, a hotter year. The analysis of variance findings provides insight into the effects of additional factors and the relationships between maize grain components. Protein and -ΣNEAA levels were greatly improved by N treatment in any growing season. Oil and fatty acid levels were typically shown to rise with both high irrigation and N rate, but increasing N had no impact when irrigation was kept low. Starch content was greater in the KSC704 cultivar, but amino acid concentration was higher in the KSC260 variety. Planting sooner resulted in a greater ΣSFA. In many cases, the oil and fatty acids levels went up when the irrigation and N rates were both high, but the increased N rate had no impact when the irrigation was low. KSC704 had greater starch absorption, whereas KSC260 had more amino acids. As stand times were accelerated, ΣSFA levels increased. Although there were noticeable variations between the two cultivars research, the findings might benefit from confirmation from research involving a larger number of cultivars. Variations in environmental variables' impacts on amylose, amylopectin, and amino acids from year to year imply that cultivars' responses to their surroundings significantly influence the ultimate starch and protein composition. These results demonstrate the complex interplay between experimental parameters and the substantial effects of weather throughout the growing season on the qualitative characteristics of maize grain.

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Authors declare that there is no conflict of interest.

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