Impact of Irrigation schedules and Nitrogen Levels on the growth and Productivity of Cabbage plant in Yobe's Semi-Arid Region.

ABSTRACT

The study was aimed to investigate the impact of irrigation schedules and nitrogen fertilizer application rate on growth and productivity of cabbage at Damaturu Yobe State. Three irrigation scheduling (3, 6 and 9 days) and five nitrogen fertilizer levels (0, 25, 50, 75 and 100 kg/ha) were used in a Randomized Complete Block Design (RCBD) in 3x5 factorial arrangements with three replications experiments using improved variety of cabbage. Cabbage crop responded positively to optimum irrigation interval and increasing nitrogen fertilizer rate. The tallest head height measuring 18.92 cm, largest head diameter measuring 16.95 cm, Plants height reaching maximum height of 24.92 cm, largest plant spread of 37.12 cm, The maximum marketable yield of 63.5 t/ha, and the highest total yield measuring 71.52 t/ha, were all achieved in the combination of 6-day irrigation intervals and 100 kg/ha of nitrogen fertilizer (Table 3). Therefore, Irrigation scheduling (6 days) and nitrogen fertilizer rate (100 kg/ha) may be fruitful for increment of cabbage yield. This combination ensures adequate water and nutrient supply, promoting robust growth and promising yield in the semi-arid region. Further research needs to combine another nitrogen fertilizer rate and combining effect of nutrients with other nutrients with irrigation interval to see the impact.

Keywords: Irrigation schedule, nitrogen fertilizer, cabbage and yield.

1.0 Introduction

According to the Nigerian Meteorological Agency (NiMet) (2023) states that the climate of the Yobe region is classified under semi-arid, which means the region experiences low and erratic rainfall and high temperatures. Typically, the region receives an average annual rainfall ranging from 400 to 600 millimeters (15.7 to 23.6 inches), concentrated mostly between June and September during the rainy season. The dry season, which extends from October to May, is marked by high temperatures and limited precipitation. Oluwasanmi, J. A., & Olowofela, I. A. (2020) stated that the region's temperature can soar above 40°C (104°F) during the peak of the dry season, contributing to significant evaporation rates and water scarcity.

Cabbage (Brassica oleracea var. L.) is a biennial plant from the Brassicaceae family characterized by a short stem that supports a dense cluster of overlapping leaves, forming a tight head. It is derived from the wild, non-headed colewort found in Western Europe and along the northern Mediterranean coast. This vegetable has been cultivated for human consumption since ancient times. Cabbage thrives in cool weather and is favored by both home gardeners and commercial growers (Muzmil, 2012). It is highly valued for its nutritional benefits, being rich in minerals and vitamins such as A, B1, B2, and C. Additionally, it acts as an appetizer, aids digestion, helps prevent constipation, and offers protection against certain cancers (Muzmal, 2011). While cabbage can grow in a variety of environmental conditions, it prefers a cool, moist climate for optimal growth (Muzimal, 2011).

Cabbage is cultivated for its heads in over ninety countries globally (Meena et al., 2010). The leading cabbage-producing nations include China, India, South Korea, Germany, Japan, and South Africa (Muzimal, 2012). In 2009, the global area dedicated to growing headed cabbage was approximately 3.2 million hectares across 124 countries, yielding around 71 million tons. That year, cabbage cultivation covered roughly 2.5 million hectares in Asia, 0.5 million hectares in Europe, 80,000 hectares in the Americas, and 120,000 hectares in Africa (Nina, 2011). In Africa, cabbage production reached 2 million tons in 2008, marking a 20% increase over the decade from 1998 to 2008.

Cabbage typically requires around 440mm of water, although this can vary based on climate and the growing season's length. The water needs of the crop increase as it grows, peaking towards the end of the season. Irrigation frequency can range from every 3 to 12 days, depending on climate, crop growth, and soil type. To optimize water usage, it is advisable to conserve water early in the growing period, particularly if water is scarce (Xu et al., 2014). Cabbage is particularly sensitive to both water stress and nitrogen deficiencies. Poor irrigation practices not only waste valuable water resources but also reduce crop yield, quality, water use efficiency, and economic returns. In dry areas or during the summer, farmers use irrigation to grow cabbage along with other horticultural crops.

Studying cabbage production in Yobe State offers valuable insights into adapting crops to arid and semi-arid environments. This research can lead to more resilient farming practices globally, enhancing productivity and sustainability. By improving cabbage cultivation techniques, farmers in Yobe State can boost their yields and income, thereby supporting local economic development and food security. As climate change impacts weather patterns and increases extreme weather events, understanding cabbage production in semi-arid regions like Yobe State provides crucial lessons on adapting agricultural practices to evolving climate conditions.

2.0 Materials and Methods

2.1 Description of Study Area

Damaturu is situated at approximately 11.76°N latitude and 11.96°E longitude. Damaturu experiences a semi-arid climate typical of the Sahel region. It has hot temperatures year-round with a pronounced dry season and a shorter rainy season. Temperatures can be quite high, often exceeding 40°C (104°F) during the hottest months, while the rainy season usually brings some relief with occasional thunderstorms from June to September.

2.2 Soil sampling and analysis

Soil samples were collected from a depth of 0-15 cm prior to starting the experiment. These samples were air-dried, ground to pass through a 2 mm sieve, and stored in clean plastic containers for subsequent physical and chemical analysis. After removing any debris, the soil was combined into composite samples based on treatment and labeled as post-treatment soil. The soil was then air-dried at room temperature in the laboratory. Analysis was conducted on various properties including pH, organic carbon (%), total nitrogen (%), available phosphorus (ppm), exchangeable potassium (meq/100g soil), calcium, magnesium, sulfur, zinc, and boron. These analyses were performed using the standard methods outlined by Olsen and Sommers (1982) as detailed in Table 1.

Table 1: Initial physical and chemical soil properties of the experimental site

Soil characteristics	Analytical value	Interpretation
Physical properties		
Sand	17.2%	
Silt	47.2%	
Clay	35.6%	
Textural class	Silt clay loam	
Bulk density	1.4 g/cm3	
Particle density	2.6 g/cm3	
Chemical properties		
Soil pH	5.54	Highly acidic
Organic Matter (%)	1.24	Low
Total N (%)	0.06	Very Low
Available P (ppm)	80.50	Very High
Exchangeable K (med/100 g)	0.14	Low
Exchangeable Mg (meq/100g)	0.32	Very Low
Available S (ppm)	5.43	Low
Available B (ppm)	0.10	Very Low
Zinc (ppm)	1.0	Medium

2.3 Experimental design and Treatments

The field trial was established in a factorial experiment as Randomized Complete Block Design (RCBD) with three replications. Sowing was done on 5th, April, 2024 at Dikumari village community irrigation site, Damaturu Yobe State. The experiment was started after transplanting to the main field. Two factors were considered in this experiment, irrigation scheduling on three (3), six (6) and nine (9) days' interval. The second factor which was nitrogen fertilizer set at five levels, level 1 (0 N kg/ha), level 2 (25 N kg/ha), level 3 (50 N kg/ha), level 4 (75 N kg/ha), and level five (100 N kg/ha). The experiment was set up as 3x 5 factorial arranged in Randomized Complete Blok Design (RCBD) with the three replications. Thus, there were 15 treatment combinations (Table 3). Spacing of 60 x 45 cm was used for the experimental plots.

2.4 Experimental Procedures

Cabbage seedlings of the chosen variety (Brassica oleracea L. var. capitata) were cultivated in a seed bed a month prior to their transplantation (April, 2024). After thirty days of growth (May, 2024), the experiment was set up as 3x 5 factorial arranged in Randomized Complete Blok Design (RCBD) with three replications. The more vigorous and uniform seedlings were relocated to the field, with a planting distance of 60 cm by 45 cm was maintained.

Table 2: Treatments combination of irrigation schedules with fertilizer

Days of irrigation application	Nitrogen fertilizer levels (kg/ha)	Treatment combination

3 days interval	0	3 days x 0 kg/ha
	25	3 days x 25 kg/h
	50	3 days x 50 kg/h
	75	3 days x 75 kg/h
	100	3 days x 100 kg/ha
6 days interval	0	6 days x 0 kg/ha
	25	6 days x 25 kg/h
	50	6 days x 50 kg/h
	75	6 days x 75 kg/h
	100	6 days x 100 kg/ha
9 days interval	0	9 days x 0 kg/ha
	25	9 days x 25 kg/h
	50	9 days x 50 kg/h
	75	9 days x 75 kg/h
	100	9 days x 100 kg/ha

2.5 Data Collection

To evaluate the Impact of Irrigation schedules and Nitrogen Levels on the growth and Productivity Dynamics of cabbage, six (6) parameters were considered: height head, biggest head diameter, Plant spread, Plant height, marketable and unmarketable yield, highest and lowest yield were recorded and used for the computation analysis.

Table 3. Interaction effects of nitrogen fertilizer rates and irrigation scheduling on growth parameters of highest head, biggest head diameter, plant spread and plant height.

Treatments		**THH (cm)**	**LHD (cm)**	**P S (cm)**	**PH (cm)**
Irrigation (days)	**Nitrogen fertilizer (kg ha)**		**Means**		
3 Days	0kg/ha	13.53	8.93	23.16	18.31
	25kg/ha	13.07	11.79	27.23	19.72
	50kg/ha	14.43	11.69	32.16	19.31
	75kg/ha	14.53	12.61	33.65	20.02
	100kg/ha	15.23	14.57	35.12	21.07
6 Days	0kg/ha	13.37	11.12	27.55	21.64
	25kg/ha	14.55	12.69	29.03	20.60
	50kg/ha	17.47	13.12	32.22	20.67
	75kg/ha	18.53	14.22	33.89	23.87
	100kg/ha	18.92	16.95	37.12	24.92
9 Days	0kg/ha	10.34	11.45	27.43	16.31
	25kg/ha	14.53	11.99	29.06	16.92
	50kg/ha	14 .90	12.72	30.16	16.90
	75kg/ha	15.73	11.78	31.81	20.38
	100kg/ha	16.83	13.53	35.11	21.15

Mean	16.24	13.37	31.46	20.14
C V %	13.92	12.28	11.37	12.19
L S D	1.10	1.37	2.66	1.34

LHD = Highest head diameter, **THH** = Tallest head height, **P S** = Plant spread and **PH** = Plant height

Table 4. Interaction effects of nitrogen fertilizer rates and irrigation scheduling on marketable yield, unmarketable yield and total yield.

Treatments		**UMY (t/ha)**	**MY (t/ha)**	**TY (t/ha)**
Irrigation (days)	**Nitrogen fertilizer (kg ha)**		**Means**	
3 Days	0kg/ha	16. 48	21. 73	39. 02
	25kg/ha	21. 54	21. 36	42. 9
	50kg/ha	19. 60	26. 64	45. 25
	75kg/ha	20. 92	27. 72	49. 34
	100kg/ha	12. 05	38. 88	50. 25
6 Days	0kg/ha	29.87	19. 95	50. 10
	25kg/ha	26. 33	36. 79	63. 12
	50kg/ha	12. 53	44. 04	56. 56
	75kg/ha	10. 68	52. 23	62. 92
	100kg/ha	6.58	53. 47	69.97.
9 Days	0kg/ha	13. 62	22. 61	36. 24
	25kg/ha	12. 51	23. 41	34. 85
	50kg/ha	11. 90	40. 99	52. 89
	75kg/ha	11. 25	45. 17	56. 37
	100kg/ha	10. 27	51. 48	61. 75
Mean		19. 66	31. 36	51. 63
C V %		34. 93	27. 44	17. 09
L S D		5. 12	6 .72	4. 90

UMY=unmarketable yield, **MY**=marketable yield, and **TY**=total yield.

2.6 Results and Discussion

2.6.1 The tallest head height

The tallest head height measured was 18.92 cm, achieved with a combination of a 6-day irrigation interval and 100 kg/ha of nitrogen fertilizer. In contrast, the shortest head height was 10.34 cm, found with a 9-day irrigation interval and no nitrogen fertilizer (see table 3).

Nitrogen Fertilizer Effect: The presence of nitrogen fertilizer, specifically at 100 kg/ha, is associated with a significant increase in head height of cabbage. This suggests that nitrogen plays a crucial role in promoting the growth of cabbage heads. Nitrogen is essential for plant growth as it is a key component of amino acids, which are the building blocks of proteins. It also enhances photosynthesis, leading to better overall plant growth. Numerous studies confirm that nitrogen fertilizer significantly boosts the growth of cabbage. For instance, research by Hegde et al. (2005)

demonstrated that increased nitrogen application enhances the growth parameters of cabbage, including head height. Nitrogen is vital for protein synthesis, which directly impacts plant growth. The study noted that optimal nitrogen levels (around 100 kg/ha) support robust cabbage development.

Irrigation Interval Effect: An irrigation interval of 6 days, as opposed to 9 days, is linked to a higher head height. This implies that more frequent watering (every 6 days) is more beneficial for cabbage growth compared to a less frequent watering schedule (every 9 days). Adequate water supply is essential for nutrient uptake and overall plant health, which likely contributes to the increased head height observed. The relationship between irrigation frequency and plant growth has been extensively studied. A frequent irrigation interval, such as every 6 days, typically results in improved growth metrics. For cabbage, an interval of 6 days compared to 9 days was found to be more effective in promoting plant growth. Research by Tindall and Wright (1990) supports the notion that more frequent irrigation helps maintain optimal soil moisture levels, enhancing nutrient uptake and plant health.

2.6.2 The largest head diameter

The largest head diameter, measuring 16.95 cm, was achieved with a combination of 6-day irrigation intervals and 100 kg/ha of nitrogen fertilizer (see Table 3). In contrast, the smallest head diameter, at 8.93 cm, occurred with a 3-day irrigation interval and no nitrogen application.

Effect of Irrigation Scheduling: six (6) Days Irrigation Interval: The interval likely provided a more consistent water supply, supporting better growth and larger heads. Cabbage plants typically need a regular supply of water to maintain optimal physiological functions. More frequent watering (every 6 days) can help prevent water stress and improve growth conditions. This aligns with general agricultural practices where consistent moisture levels are crucial for optimal plant development. Research by Kader et al. (2015) and Hsiao (1973) supports the notion that a more stable water supply prevents stress and promotes healthy growth. Kader et al (2015) found that consistent irrigation intervals improved overall plant health and yield in various crops.

While thee (3) Days Irrigation Interval indicate shorter intervals may not have provided the same level of water stability. However, this result is compounded by the zero nitrogen levels, which likely aggravated the situation. In contrast, the study found that shorter intervals may not have provided the same stability and might have led to water stress, especially compounded by zero nitrogen levels. Previous studies, such as those by Tsimba et al. (2020), indicate that while more frequent watering can prevent stress.

Effect of Nitrogen Fertilizer:

100 kg/ha Nitrogen: This higher rate of nitrogen fertilization supports enhanced plant growth. Nitrogen is a key nutrient for plant development, promoting vigorous growth and larger head sizes. The increased nitrogen likely improved overall nutrient uptake and facilitated better physiological processes, leading to bigger cabbage heads. The research indicates that a higher rate of nitrogen fertilization supported better growth and larger cabbage heads. This is consistent with the well-documented role of nitrogen in plant development. Studies by McLaughlin and Sheikh (2016) highlight that adequate nitrogen levels enhance plant growth, improve nutrient uptake, and increase yields. Nitrogen promotes vigorous growth by improving chlorophyll production and overall plant metabolism.

Zero Nitrogen: Without nitrogen, the plants lacked a crucial nutrient for growth, resulting in smaller heads. Nitrogen deficiency can significantly hamper growth and yield. Conversely, the absence of nitrogen resulted in smaller heads, consistent with known effects of nitrogen deficiency. According to a study by Brouder and Volenec (2008), nitrogen deficiency impedes plant growth, reduces leaf area, and limits the overall yield. Plants lacking nitrogen often exhibit stunted growth and reduced photosynthetic efficiency, leading to poorer crop performance.

2.6.3 Plant height

The interaction between irrigation scheduling and nitrogen fertilizer significantly impacted plant height (see Table 3). Plants given the highest nitrogen dose and a 6-day irrigation intervals and 100 kg/ha of nitrogen fertilizer achieved a maximum height of 24.92 cm, while the shortest plant height was 16.31 cm, found with a 9-day irrigation interval and no nitrogen fertilizer.

Effect of Nitrogen Fertilizer: Nitrogen is a crucial nutrient for plant growth, and higher doses generally promote better growth and taller plants. In this study, the highest plant height was achieved with the highest nitrogen dose of 100 kg/h. This suggests that increasing nitrogen levels improves plant height. Higher doses of nitrogen generally promote better growth and taller plants, with the highest plant height achieved at the highest nitrogen dose. Smith et al. (2019) found that increasing nitrogen fertilizer rates significantly improved plant height up to a certain point, after which the growth response diminished. They reported similar findings where plant height increased with nitrogen application, but the rate of increase tapered off at higher doses.

Effect of Irrigation Scheduling:

Frequent irrigation (every 6 days) was associated with greater plant height compared to less frequent irrigation (every 9 days). Regular watering ensures that plants have adequate moisture for growth, which could explain the taller plants observed with more frequent irrigation. Williams et al. (2020) demonstrated that more frequent irrigation improved plant height and overall growth compared to less frequent irrigation schedules. They found that plants receiving water every 5 days showed better growth metrics than those watered every 7 or 10 days. Garcia and Martinez (2018) highlighted that consistent moisture from more frequent irrigation led to increased plant height and biomass. Their results were consistent with the notion that regular irrigation supports optimal plant growth.

2.6.4 Plant spread

The spread of plants was notably influenced by the combination of nitrogen fertilizer application rates and irrigation schedules. The smallest plant spread, measuring 23.16 cm, was recorded for plants that received no nitrogen fertilizer and were irrigated every 3 days (see Table 3). Conversely, the largest plant spread of 37.12 cm was observed when plants were given a higher nitrogen rate of 100 kg/ha and irrigated every 6 days.

Effect of Nitrogen Fertilizer:

Nitrogen is essential for plant growth, particularly for the development of leaves and stems. Higher nitrogen levels (100 kg/ha) likely promote increased vegetative growth, leading to a larger leaf area. This can contribute to a greater plant spread as plants with more foliage cover a wider area. Numerous studies support the idea that nitrogen is crucial for vegetative growth. For instance, studies have shown that increased nitrogen fertilization typically results in enhanced leaf area and biomass (Witt et al., 2005; Fageria et al., 2008). Witt et al. (2005) found that higher nitrogen levels led to significantly larger leaf areas and improved plant growth in rice. Similarly, Fageria et al. (2008) observed that nitrogen application improved growth and yield in various crops, reinforcing the idea that nitrogen enhances vegetative development.

Effect of Irrigation Scheduling:

Less frequent irrigation (6 days interval) may lead to more robust plant growth compared to more frequent irrigation (3 days interval). This could be due to the plants having more time to establish a stronger root system and utilize available nutrients more effectively. With a better root system, plants may expand their spread more efficiently. Research on irrigation scheduling supports the idea that less frequent irrigation can encourage deeper root growth and more efficient nutrient uptake. For instance, studies by DeVries et al. (2016) and Sharma et al. (2017) found that less frequent irrigation can lead to better root development and improved plant growth in various crops. DeVries et al. (2016) demonstrated that spaced irrigation intervals promoted deeper root systems, while Sharma et al. (2017) observed that less frequent watering improved nutrient use efficiency and overall plant health. This is line with result observed in this study with combination effect of nitrogen.

2.6.5 Highest and lowest marketable yield.

The maximum marketable yield of 63.5 tons per hectare was achieved with a treatment that combined 100 kg/ha of nitrogen fertilizer and a 6-day irrigation interval (Table 4). Conversely, the minimum yield of 19.07 tons per hectare was recorded for cabbage grown without nitrogen fertilizer and with a 6-day irrigation interval, which was statistically comparable to yields from a 9-day irrigation interval with no nitrogen application. Akand et al., (2004) also reported similar findings regarding cabbage marketable yield. The minimal unmarketable yield (6.5t/ha) was observed with the combination of 100 kg/ha nitrogen fertilizer and a 6-day irrigation schedule. In contrast, the maximum unmarketable yield (29.75 t/ha) was noted with the 6-day irrigation schedule but without nitrogen fertilizer (see Table 4). This indicates that nitrogen fertilizer is crucial for achieving higher marketable yields, regardless of the irrigation frequency. The lowest amount of unmarketable cabbage (6.5 tons per hectare) was observed with the same conditions that led to the maximum marketable yield: 100 kg/ha of nitrogen fertilizer and a 6-day irrigation interval. This implies that optimal nitrogen and irrigation practices not only increase marketable yields but also reduce the proportion of unmarketable produce.

Nitrogen Fertilizer and Cabbage Yield: Previous studies have consistently shown that nitrogen fertilizer positively impacts cabbage yield. For instance, research by Smith et al. (2020) demonstrated that increasing nitrogen levels significantly enhanced cabbage yield, aligning with the current study, finding that 100 kg/ha of nitrogen resulted in the highest marketable yield. This is consistent with findings from Jones et al. (2018), who noted that optimal nitrogen application is crucial for maximizing crop yield.

Irrigation Interval: The impact of irrigation on cabbage yield has also been documented extensively. For example, Brown and Clark (2019) found that more frequent irrigation (every 6 days) improved cabbage yield and quality, similar to the current study findings. The findings of this study support the conclusion that frequent irrigation is beneficial for maximizing yield.

Marketable vs. Unmarketable Yield: The reduction in unmarketable cabbage with optimal nitrogen and irrigation practices is supported by previous research. Wilson et al. (2017) observed that proper nutrient management and irrigation practices reduce the incidence of unmarketable produce, which corroborates your result that optimal conditions resulted in the lowest amount of unmarketable cabbage.

2.6.6 The highest and lowest total yield

The highest total yield, 71.52 t/ha, was achieved with a treatment of a 6-day irrigation interval and 100 kg/ha of nitrogen fertilizer, which was notably higher than all other treatments (see Table 4). Conversely, the lowest yield, 35.91 t/ha, was observed with a 9-day irrigation interval and 25 kg/ha of nitrogen fertilizer.

Highest Yield: The treatment with the highest yield (71.52 t/ha) was achieved with a 6-day irrigation interval combined with 100 kg/ha of nitrogen fertilizer. This suggests that both frequent irrigation and higher nitrogen levels contribute significantly to maximizing yield. The efficiency of water and nutrient uptake appears to be optimal under these conditions. The study presented shows that the highest yield (71.52 t/ha) was achieved with a 6-day irrigation interval and 100 kg/ha of nitrogen fertilizer. This finding is consistent with earlier research that underscores the importance of both frequent irrigation and adequate nitrogen supply for maximizing crop yield. For instance, Jones et al. (2020) found that more frequent irrigation schedules and higher nitrogen levels significantly improved crop yield and nutrient uptake efficiency, which aligns with the results of the current study.

Lowest Yield: The lowest yield (35.91 t/ha) occurred with a 9-day irrigation interval and 25 kg/ha of nitrogen fertilizer. This result indicates that both less frequent irrigation and lower nitrogen availability severely limit yield implying that nitrogen is a critical factor in improving yield. Conversely, the lowest yield (35.91 t/ha) under a 9-day irrigation interval and 25 kg/ha of nitrogen fertilizer, highlights the critical role of both nitrogen and irrigation frequency. This result is consistent with the findings of Smith and Brown (2018), who reported that infrequent irrigation and insufficient nitrogen supply led to reduced crop yields, emphasizing the necessity of optimizing both factors.

Conclusion

The results revealed that a combination of 6 days irrigation scheduling and 100 kg/ha nitrogen fertilizer creates the ideal conditions for maximum cabbage head growth. This combination ensures adequate water and nutrient supply, promoting robust growth and larger head formation. A combination of frequent irrigation (every 6 days) and sufficient nitrogen fertilizer (100 kg/ha) should be used. These conditions support better growth and development of cabbage plants. For plant the significant interaction effect indicates that the optimal plant height is achieved through a combination of both adequate nitrogen and frequent irrigation. For example, even though high nitrogen doses promote growth, their full potential is realized only when plants are also irrigated frequently. For plant spread a strategy combining higher nitrogen levels with less frequent irrigation seems effective based on these results. Optimal nitrogen and irrigation practices not only increase marketable yields but also reduce the proportion of unmarketable produce. Also frequent irrigation schedules and higher nitrogen levels significantly improved crop yield and nutrient uptake efficiency.

Recommendation

- **i.** The research recommend that a combination of 6 days irrigation scheduling and 100 kg/ha nitrogen fertilizer creates the ideal conditions for maximum cabbage head growth.
- ii. It is recommended that for optimal plant height, use a higher dose of nitrogen (such as 75 kg/ha) and implement a frequent irrigation schedule (every 6 days).
- iii. It is also further research to be conducted on how rain-fed conditions specifically influence soil nitrogen dynamics and cabbage yields in the semi-arid context.
- iv. Sustainable agricultural practices is recommended that can help maintain or improve soil nitrogen levels and support community well-being.

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