Effect of tillage and nutrient management practices on normalized difference vegetation index of maize

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ABSTRACT

Aims: The objective of the experiment was to study the NDVI values of maize crop at knee height stage and pre tasseling stage as an indicator of crop health, under different tillage practices and precision nutrient management strategies.
Study design: The experiment was conducted in split plot design using six tillage practices (Conventional Tillage, Conventional Tillage + Chisel Plough, Permanent Ridges, Permanent Bed, Zero Tillage and Minimum Tillage) in main plots and three nutrient management strategies [Site-Specific Nutrient Management (SSNM), GreenSeeker guided nitrogen application (GS), and 100% Recommended Dose of Nutrients (RDN)] in sub plots.
Place and Duration of Study: The field experiment was conducted in E-2 block (Maize Agronomy block) of Norman E. Borlaug Crop Research Centre at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India. The field experiment was conducted for two years (2022-23 and 2023-24).
Methodology: Conventional tillage involved two passes of harrowing and one rotavator. Conventional tillage + chisel plough included the additional use of a chisel plough after every four years. In permanent ridge and permanent bed strip, raised soil configurations were reshaped after every crop. In zero tillage, land preparation was limited to opening of seed furrows and crop was sown directly. In minimum tillage field was tilled through only single pass of rotavator was. In SSNM using "Maize Nutrient Expert" nutrient application was done at the rate 130:33:66 kg N: P_2O_5: K_2O per ha. Under GS treatments maize nitrogen application was done as (40 + GS) N per ha. The 100% RDN for maize is 120:60:40 kg N: P_2O_5: K_2O per ha.

Results: Results indicated significant variations in NDVI values at knee height stage and at pre tasseling stage due to different tillage practices where zero tillage and conventional + chisel plough were found significantly superior. NDVI values among nutrient management strategies were not statistically different. Correlation studies concluded that NDVI of *kharif* maize crop is negatively correlated to minimum temperature, maximum temperature, number of rainy days and amount of rainfall received.
Conclusion: Zero tillage can be advocated for the better health of kharif maize crop.

Keywords: Chisel Plough, GreenSeeker, Minimum tillage, NDVI, Site-Specific Nutrient Management, Zero Tillage

1. INTRODUCTION

Maize is cultivated in over 170 countries, covering 193.7 million hectares, and boasts the highest productivity among cereals at 5.9 tons per hectare, with a total production of 1147.7 million ton [1]. In India, maize is grown year-round on 10.5 million hectares, yielding 38.0 million ton with productivity of 3.6 tons per hectare [1]. The significant gap between global and national productivity level highlights the need for adopting modern crop production technologies instead

of conventional practices. The adoption of recent advancements may boost maize growth and thereby productivity along with environmental sustainability. One promising path to achieve this is through modern forms of tillage and precision nutrient management. Unlike conventional tillage, modern tillage improves soil health, soil structure, organic matter content, and moisture retention, promoting healthier crop growth, enhanced root development, and higher yields [2]. By protecting the soil surface, conservation tillage reduces erosion, maintains soil fertility, and contributes to better growth and yields [3]. Precision nutrient management practices are known to enhance nutrient use efficiency, productivity and profitability in accordance with environmental sustainability [4]. Crops show significant responses to precise nutrient applications, reflected in increased chlorophyll content and higher NDVI values soon after application. Consistent, precise nutrient management ensures that crops receive the right amount of nutrients throughout the growing season, promoting optimal growth [5].
Combining modern tillage with precision nutrient management creates a synergistic effect that significantly enhances crop health [6]. Long-term modern tillage and nutrient management improves overall soil fertility, supporting healthier crops and sustained higher NDVI values over multiple growing seasons [7]. Together, these practices contribute to improved crop health and productivity, minimizing the environmental impact of farming, thereby promoting healthier ecosystems and more stable vegetation indices [8].
Crop health indicators are essential for assessing the impact of agricultural inputs on crops. These indicators include visual cues (such as leaf color, shape, size, and vigor) and physiological measures (such as chlorophyll content measured with SPAD meters and stomatal conductance), which help to evaluate crop health at various growth stages and the effects of treatments of crop. The Normalized Difference Vegetation Index (NDVI) is a numerical indicator derived from the visible and near-infrared bands of the electromagnetic spectrum and is used to determine the presence of live green vegetation [9]. Based on remote sensing principles, NDVI assesses vegetation health, biomass, and chlorophyll content, making it a vital tool for monitoring crop growth and development and providing critical information for agronomic decision-making. NDVI values range from -1 to +1, and they are calculated using the following formula

Where:
NIR (Near-Infrared): Reflectance in the near-infrared region of the spectrum.
R: Reflectance in the red region of the spectrum.
ref: Reflected
inc: incident
NDVI values close to +1 indicate healthy, dense green vegetation while values close to zero suggest sparse vegetation or bare soil. Healthy, photosynthetically active vegetation reflects more near-infrared (NIR) light and less visible light, resulting in higher NDVI values. It detects plant stress caused by factors such as nutrient deficiencies, allowing for timely interventions. High NDVI values generally correlate with higher biomass and potential yield.
Considering the foresaid points, an experiment was planned to assess the health and performance of maize crop under modern tillage and precision nutrient management practices through NDVI reflectance. The objective of the experiment was to study the NDVI values of maize crop at knee height stage and pre tasseling stage as an indicator of crop health, under different tillage practices and precision nutrient management strategies. By understanding these effects, the study aims to provide insights into optimizing tillage and nutrient management practices for improved crop health and yield.

2. material and methods

2.1 Experimental site

The field experiment was conducted in E-2 block (Maize Agronomy block) of Norman E. Borlaug Crop Research Centre at Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India. The field experiment was conducted for two years (2022-23 and 2023-24). The site is situated at an altitude of 243.84 m above mean sea level, at 29° N latitude and 79.5° E longitudes under narrow belt of Shivalik foothills called *Tarai*. Accounts of weather parameters during experimental period were obtained from the meteorological observatory located at N. E. Borlaug Crop Research Centre, Pantnagar and are depicted in Fig. 1

2.2 Treatment details

The experiment was a part of long term field study initiated in 2012. Conducted using a Split-Plot Design with three replications, the main plot treatments consisted of six tillage practices: conventional tillage, conventional tillage + chisel plough, permanent ridges, permanent bed, zero tillage and minimum tillage. Conventional tillage involved two passes of harrowing and one rotavator to prepare the seedbed. conventional tillage + chisel plough included the additional use of a chisel plough after every four years to break up compacted soil layers, improving root penetration and water infiltration. In permanent ridge and permanent bed strip, raised soil configurations that were made in 2012 remained intact throughout multiple growing seasons and were reshaped after every crop. In zero tillage, land preparation was limited to opening of seed furrows and crop was sown directly. Minimum tillage omitted few tillage operations that were performed under conventional tillage and only single pass of rotavator was done.

The sub-plot treatments included three nutrient management strategies: Site-Specific Nutrient Management (SSNM), GreenSeeker Guided Nitrogen Application (GS), 100% Recommended Dose of Nutrients (RDN). SSNM involved tailoring nutrient applications to the specific needs of different field zones based on soil tests, crop requirements, and yield goals. This approach optimizes nutrient use efficiency and minimizes environmental impact. Using “Maize Nutrient Expert” nutrient application was done at the rate 130:33:66 kg N: P_2O_5: K_2O per ha. GreenSeeker is a precision agriculture tool that uses optical sensors to assess crop health and guide variable-rate nitrogen applications. It ensures that nitrogen is applied where and when it is needed most, improving nitrogen use efficiency and crop yield. Under GS treatments maize nitrogen application was done as (40 + GS) N per ha. 40 kg N per ha was given as prescriptive basal dose and top dressing at knee height and pre tasseling stage was done as GreenSeeker guided nitrogen application. Prior to applying fertilizer, NDVI readings from both N-rich strip and test plots were collected and used to calculate urea application dose. The 100% RDN strategy involved applying the full recommended dose of nutrients based on general crop requirements and soil tests. While it ensures sufficient nutrient availability, it may not account for spatial variability within the field. The recommended dose of nutrients for maize is 120:60:40 kg N: P_2O_5: K_2O per ha.

Fig 1: Meteorological parameters during the years of experimentation (Kharif 2022 and kharif 2023) recorded at the meteorological laboratory of NEB, Crop Research Centre, GBPUAT, Pantnagar

2.3 Recording of NDVI values

A handheld GreenSeeker was used to determine NDVI value of crop and monitor crop health under different treatments. NDVI values were determined at knee height stage, *i.e.*, 33 days after sowing (DAS) and pre tasseling stage i.e., 55 DAS of maize. GreenSeeker was used either before 10 am in the morning or after 3 pm in the afternoon on a clear sunny day to avoid the direct interference of overhead sunlight in estimation. The instrument was held at 60 cm above the crop canopy while the trigger was pulled. The instrument thereafter displayed the measured NDVI reading on the LCD display immediately.

2.4 Statistical Analysis

Data for NDVI reading was analyzed for variance at the 5% level of significance using Fischer's method of analysis of variance. Significant treatment differences were evaluated using the value of critical difference. Statistical analysis of all parameters was carried out utilizing the split-plot design methodology as described by Gomez and Gomez [10] with the help of OPSTAT software. The OriginPro 2024b software was used for correlation studies between NDVI values of maize and weather parameters.

3. results and discussion

3.1 Effect of Tillage Practices on NDVI of maize

NDVI value increased with advancement in crop age from 33 DAS to 55 DAS in all tillage treatments. Data (Table 1 and fig 2) revealed that at 33 DAS in 2022, field preparation through conventional tillage + chisel plough exhibited the highest NDVI reflectance (0.792) which was at par with zero tillage (0.787), indicating robust early vegetative growth in these tillage practices. These treatments were significantly superior to conventional tillage (0.711), permanent ridge (0.724), permanent bed (0.730) and minimum tillage (0.753). Minimum tillage had moderate NDVI value, which was statistically at par with permanent bed and permanent ridge while it was significantly more than conventional tillage. At 33 DAS in 2023, zero tillage (0.741) and conventional tillage + chisel plough (0.739) showed the significantly higher NDVI values, which were at par with minimum tillage (0.719) but statistically outperformed conventional tillage (0.698), permanent bed (0.710) and permanent ridge (0.700). Maize crop grown under conventional tillage, permanent bed and permanent ridge showed poor reflectance and these treatments were statistically at par with each other in second year of experimentation.

	NDVI Values at knee height stage (33 DAS)		**NDVI Values at pre-tasseling (55 DAS)**	
	2022	2023	2022	2023
Main plot: Tillage Treatments				
Zero Tillage	0.787	0.741	0.810	0.785
Conventional Tillage	0.711	0.698	0.777	0.764
Permanent Bed	0.730	0.710	0.782	0.762
Permanent Ridge	0.724	0.700	0.786	0.765
conventional tillage + Chisel plough	0.792	0.739	0.811	0.785
Minimum Tillage	0.753	0.719	0.803	0.773
SEm±	0.005	0.008	0.006	0.005

LSD (p=0.05)	0.017	0.026	0.020	0.015
Sub plot: Nutrient management				
Green seeker guided Nitrogen application	0.746	0.725	0.807	0.777
SSNM (125:58:65 kg $N:P_2O_5:K_2O$)	0.751	0.716	0.788	0.770
100% RDN (150:60:40kg $N:P_2O_5:K_2O$)	0.752	0.712	0.789	0.770
SEm±	0.007	0.005	0.004	0.004
LSD (p=0.05)	NS	NS	NS	NS

At 55 DAS in 2022, the conventional tillage + chisel plough treatment maintained the highest NDVI value (0.811) which was statistically similar to zero tillage (0.810) and minimum tillage (0.803) while was significantly superior to permanent ridge (0.786) and permanent bed (0.782) and minimum tillage (0.777). In 2023, both zero tillag and conventional tillage + chisel plough

showed the highest NDVI values (0.785) and these two tillage practices being at par with minimum tillage had significantly more value than conventional tillage (0.764), permanent bed (0.762) and permanent ridge (0.765). Higher value of NDVI in zero tillage, conventional tillage + chisel plough and minimum tillage indicated better growth in these tillage practices.

Table 1: NDVI values at knee height and pre-tasseling stage as influenced by tillage treatments and nutrient management practices.

Fig 2: Influence of tillage treatments on NDVI value at knee height stage (33 DAS), and pre tasseling stage (55 DAS).

Amongst tillage treatments, zero tillage and conventional with chisel plough resulted in higher NDVI as was also reported by Cai et al. [11] and Pramanick et al. [6]. Higher soil organic matter and better soil aggregation in zero tillage plots after ten years of practice have contributed to better crop growth and ultimately higher NDVI values [12, 13]. Chiseling allows more root penetration as compared to conventional tillage [14, 15] and thereby permits extraction of nutrients from deeper soil profile [16]. Moreover, chisel ploughing made more availability of nutrients from increased area of exploration by roots, improved crop health and resulted into higher reflectance and thus more NDVI value.

3.2 Effect of Nutrient Management Strategies on NDVI of Maize

An increase in NDVI value among all nutrient management practices was observed as crop age advanced from 33 DAS to 55 DAS (Table 1). Data presented in Table 1 clearly indicated that at 33 DAS the NDVI values among nutrient management practices in 2022 were not significantly different. Similarly, in 2023, GS (0.725), SSNM (0.716) and RDN (0.712) showed non-significant differences. At 55 DAS in 2022, the GS treatment had the highest NDVI value (0.807), although it was not significantly superior to the other treatments. The SSNM and 100% RDN treatments (0.790 and 0.793, respectively) were at par with each other. In 2023, NDVI values at 55 DAS did not vary significantly due to different nutrient management treatments where GS (0.777) showed a marginally higher NDVI value than SSNM (0.770) and 100% RDN (0.770).

In the nutrient management treatments, adequate amount of nutrient application satisfied vegetative nutrient demand of crop. At par crop health in all nutrient management treatments resulted in to non-significant differences in reflectance of crop.

3.3 Correlation between weather parameters and NDVI of maize

The NDVI values in the second year of study were lower as compared to that observed in first year attributing to the influence of environmental factors, notably the impact of amount, intensity and duration of rainfall on crop growth [17], temperature and number of rainy days. Meteorological data recorded during experimentation period revealed that early and mid *kharif* season of 2023 experienced the heavy rainfall which was 603.6 mm in July and 395.2 mm in August as against 174.8 mm and 182.1 mm in July and August 2022, respectively. Thus in 2023 rainfall was higher by 428.8 mm in July and 213.1 mm in August than that of in 2022. Incessant rain delayed sowing of crop, reduced sunlight availability to crop and enhanced nutrient leaching, in July 2023. Besides caused excess soil moisture for longer period and created anaerobic condition in root zone [18]. This enhanced water availability in vegetative stage most likely influenced plant NDVI [19]. All these factors together hampered crop growth in 2023 and were the main reasons that NDVI values in second years of experimentation were lower as compared to first year. Correlation studies confirm that number of rainy days (R^2 = -0.77), amount of rainfall received (R^2 = -0.46), maximum temperature (R^2 = -0.61) and minimum temperature (R^2 = -0.85) are negatively correlated with NDVI reflectance (Fig 3). It further indicates that health of *Kharif* maize has been hampered by the negative impact of high temperature, heavy rainfall and more number of rainy days experienced by the crop.

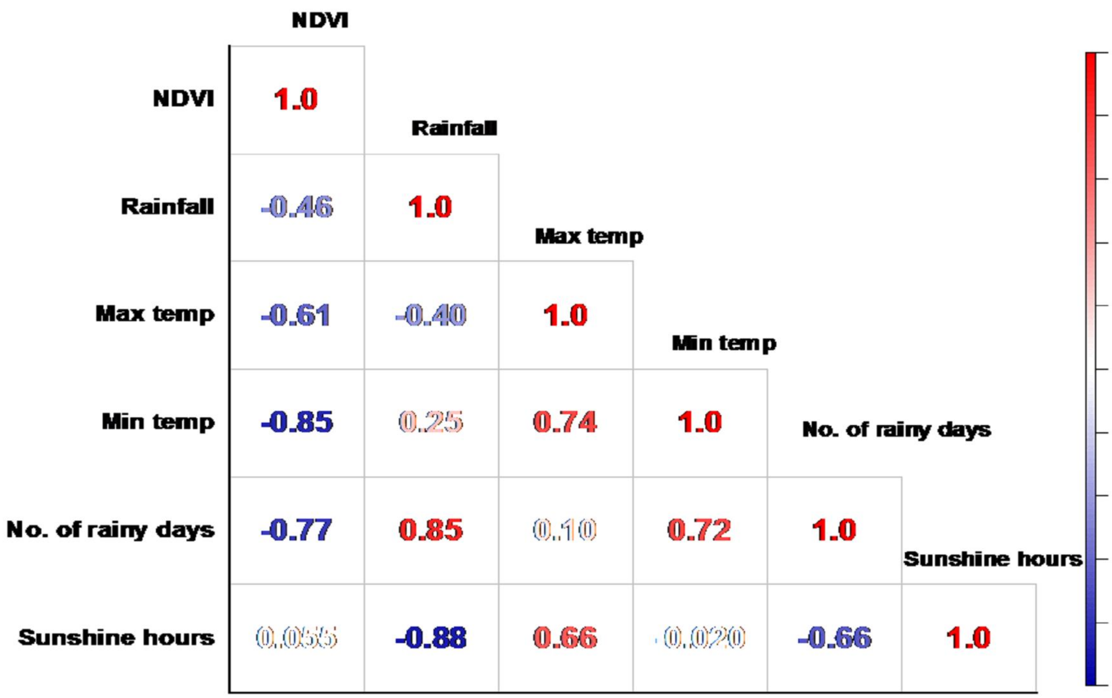

Fig 3: Correlation between NDVI of maize crop and weather parameters (Rainfall, maximum temperature, minimum temperatures, number of rainy days and sunshine hours).

4. Conclusion

In summary, overall, the study highlights the importance of selecting tillage practices that can impact crop growth and development. The zero tillage and conventional tillage + chisel plough consistently showed high NDVI values, indicating their effectiveness in promoting vegetative growth. In terms of nutrient management, all tested strategies provided similar benefits to the crop, suggesting their adaptability to sustain vegetative growth. Health of *kharif* maize was concluded to be a factor negatively influenced by rainy days, amount of rainfall received, maximum temperature and minimum temperature.

References

- ICAR-Indian Institute of Maize Research, https://iimr.icar.gov.in/
- Pooniya V, Biswakarma N, Parihar CM, Swarnalakshmi K, Lama A, Zhiipao RR, Nath A, Pal M, Jat SL, Satyanarayana T, Majumdar K. Six years of conservation agriculture and nutrient management in maize–mustard rotation: Impact on soil properties, system productivity and profitability. Field crops research. 2021;260:108002
- Zhang Y, Tan C, Wang R, Li J, Wang X. Conservation tillage rotation enhanced soil structure and soil nutrients in long-term dryland agriculture. Eur J Agron.

2021;131:126379. doi:10.1016/j.eja.2021.126379

- Anand, Satyam & Kumar, Pushpam & Alok, Ankit & Kumar, Rishikesh. 2023. Chapter -4 Precision Agriculture: Technology and Implementation.
- Jat RK, Bijarniya D, Kakraliya SK, Sapkota TB, Kakraliya M, Jat ML. Precision nutrient rates and placement in conservation maize-wheat system: effects on crop productivity, profitability, nutrient-use efficiency, and environmental footprints. Agron. 2021;11(11):2320
- Pramanick B, Kumar M, Naik BM, Kumar M, Singh SK, Maitra S, Naik BS, Rajput VD, Minkina T. Long-term conservation tillage and precision nutrient management in maize–wheat cropping system: effect on soil properties, crop production, and economics. Agron. 2022;12(11):2766.
- Parihar CM, Jat HS, Jat SL, Kakraliya SK, Nayak HS. Precision nutrient management for higher nutrient use efficiency and farm profitability in irrigated cereal-based cropping systems. Indian J. Fertilisers. 2020;16(10):1000-14.
- Sapkota TB, Majumdar K, Jat ML, Kumar A, Bishnoi DK, McDonald AJ, Pampolino M. Precision nutrient management in conservation agriculture based wheat production of Northwest India: Profitability, nutrient use efficiency and environmental footprint. Field Crops Res. 2014;155:233-244.
- Lane CR, Liu H, Autrey BC, Anenkhonov OA, Chepinoga VV, Wu Q. Improved wetland classification using eight-band high resolution satellite imagery and a hybrid approach. Remote Sens. 2014;6(12):12187-216.
- Gomez KA, Gomez AA. Statistical procedures for agricultural research. John wiley and sons; 1984 Feb 17.
- Cai H, Ma W, Zhang X, Ping J, Yan X, Liu J, Yuan J, Wang L, Ren J. Effect of subsoil tillage depth on nutrient accumulation, root distribution, and grain yield in spring maize. Crop J.2014;2(5):297-307.
- Zhang Y, Wang S, Wang H, Ning F, Zhang Y, Dong Z, Wen P, Wang R, Wang X, Li J. The effects of rotating conservation tillage with conventional tillage on soil properties and grain yields in winter wheat-spring maize rotations. Agric. For. Meteorol. 2018;263:107-17.
- Naik, B.M., 2019. *Impact of long term tillage and nutrient management practices on maize productivity and soil health* (Doctoral dissertation, DRPCAU, Pusa, Samastipur).
- Nisar S, Benbi DK. Tillage and mulching effects on carbon stabilization in physical and chemical pools of soil organic matter in a coarse textured soil. Geoderma Reg. 2024:e00827.
- Wang X, Zhou B, Sun X, Yue Y, Ma W, Zhao M. Soil tillage management affects maize grain yield by regulating spatial distribution coordination of roots, soil moisture and nitrogen status. Plos one. 2015;10(6):e0129231.
- Ramadhan MN. Yield and yield components of maize and soil physical properties as affected by tillage practices and organic mulching. Saudi J. Biol. Sci. 2021;28 (12):7152-9.
- Wang R, Cherkauer K, Bowling L. Corn response to climate stress detected with satellite-based NDVI time series. Remote Sens. 2016;8(4):269.
- Zaidi PH, Rafique S, Singh NN. Response of maize (Zea mays L.) genotypes to excess soil moisture stress: morpho-physiological effects and basis of tolerance. Eur J Agron. 2003;19(3):383-99.
- Liu K, Wiatrak P. Corn production response to tillage and nitrogen application in dry-land environment. Soil till res. 2012;124:138-43.