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Exploring Morpho-Physiological Responses of Paddy to Conventional and Natural Farming Practices in Kanumolu village of Andhra Pradesh

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Abstract: Agricultural development in India has historically relied on conventional farming, which has significantly boosted crop yields but also led to environmental concerns such as soil degradation and water pollution. In response, Zero Budget Natural Farming (ZBNF) has emerged as a sustainable alternative, focusing on organic inputs and ecological balance. This study compares the morpho-physiological characteristics of paddy crops grown under conventional farming and ZBNF practices, with a focus on two, three and four years of ZBNF adoption. The study conducted in Kanumolu village, Andhra Pradesh, the study employed a randomized block design with four treatments: NF adopted for two years, NF adopted for three years, NF adopted for four years and conventional farming. Conventional farming resulted in the highest plant population (200 plants/ m^2), plant height (65.20 cm), and leaf area per plant (2536.54 dm^2), indicating immediate growth benefits. However, it also led to environmental concerns. NF, particularly after four years, showed longer root length (23.77 cm) and thicker leaves (0.69 mm), reflecting improved root health and adaptation to organic practices. NDVI values were highest under NF adopted for four years (0.74), while conventional farming showed lower values (0.59), indicating a shift towards enhanced nutrient efficiency and root development. Correlation analysis revealed positive relationships between leaf area, NDVI, and plant height, highlighting the trade-offs in growth traits. In conclusion, while conventional farming provides short-term growth advantages, ZBNF offers a sustainable alternative with long-term benefits for soil health and ecological balance. This underscores the need for further research to balance productivity with sustainability in agricultural practices.

Keywords: Chemical farming, NDVI, Rice, ZBNF

Introduction

Agricultural development is vital for food and livelihood security in India. To tackle food shortages in the 1960s and 1970s, the Green Revolution (GR) was introduced, focusing on

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seed-fertilizer-irrigation technology. Since then, significant investments in agriculture have transformed India into a leading producer of various commodities. With only 2.43% of the world's geographical area, India ranks first in pulses, onions, and milk; second in several other major crops; and third in cereal production (Yadav and Anand, 2020). The country has shifted from a major food grain importer to a key exporter of agricultural products.

Rice (*Oryza sativa* L.), a staple food for over half the world, plays a crucial role in global food security and sustenance (Mohidem *et al.* 2022). While chemical farming has long dominated rice cultivation, leading to increased yields, it has also resulted in environmental degradation, soil depletion, water pollution, and long-term unsustainability. To counter these issues, natural farming has emerged as an alternative, focusing on organic inputs, ecological balance and sustainability. Recent agricultural advancements include replacing agrochemicals with biological and organic inputs, shifting from monocropping to mixed and tree-based cropping systems, and experimenting with techniques to reduce water usage, such as the system of rice intensification. There is also a move from isolated sectoral development to integrated approaches and a focus on applying ecological principles and services.

The morpho-physiological traits of rice, such as plant height, root length, leaf area, and tiller number, respond differently to chemical and natural farming. Chemical farming accelerates vegetative growth but often weakens plants against environmental stress. Natural farming promotes balanced growth, stronger root development and increased resilience through organic inputs, resulting in more sustainable rice production. While chemical farming boosts short-term yields, it has long-term negative consequences on soil health, water resources, and the environment. Natural farming, though producing slightly lower initial yields, offers a sustainable solution by improving soil health, conserving water, and supporting biodiversity.

Research on natural farming practices and their effects on crops, soil, and other aspects is limited and often produces mixed results. Studies have examined the role of various local inputs used in natural farming. For example, Bhadu *et al.* (2021) found that applying 8% and 10% jeevamrutha significantly increased both grain and straw yields of wheat compared to controls. Kumbar and Devakumar (2017) reported that a 2000 Liters/ha application of jeevamrutha resulted in a significantly higher green pod yield of French beans, which was further improved when supplemented with 6% PG. Similarly, Shubha *et al.* (2017) observed higher soil microbial populations and paddy yields at UAS, Bengaluru when Palekar's method was supplemented with PG. A survey across 13 districts in Andhra Pradesh indicated that Zero Budget Natural Farming (ZBNF) partially improved soil health compared to non-adopters, with higher soil organic carbon (52%) and total nitrogen (70%) but a decline in available phosphorus and zinc in ZBNF fields (Shyam *et al.*, 2019).

Khadse *et al.* (2017) highlighted several positive impacts on various agroecological indicators among the ZBNF-adopted farmer households they surveyed in Karnataka. These include improvements in soil conservation, seed autonomy, produce quality, household food autonomy, farm income, crop yield, seed diversity, and selling price. However, the authors did not provide details about the methods used to measure these indicators. Similarly, Tripathi *et al.* (2018) reported promising results, stating that farmers practicing ZBNF in Andhra Pradesh earn significantly more than conventional farmers. They also noted that ZBNF farmlands may be better able to withstand droughts, high-speed winds, and flooding compared to non-ZBNF plots. Additionally, they observed that the yields of five crops—paddy, groundnut, black gram, maize, and chilies-have increased by 8-32% for ZBNF farmers.

While many farmers across the country have voluntarily adopted these models, they often operate in isolation with limited networking. Andhra Pradesh stands out as the first state to embrace ecological farming as a state policy, with plans to transition all crop land and farmers to natural farming practices. The Government of Andhra Pradesh (GoAP) adopted Andhra Pradesh Community Managed Natural Farming (APCNF) to address various agricultural challenges. To implement APCNF statewide, GoAP established the Rhythu Sadhikara Samstha (RySS), an integrated institutional framework designed to promote this farming method. APCNF is based on Dr. Subhash Palekar's zero budget natural farming (ZBNF) model, which is rooted in principles observed in forest ecosystems. RySS is continuously adapting and enhancing the original ZBNF model to better fit local conditions and needs.

The hypothesis for this experiment is that natural farming positively influences key morpho-physiological traits of rice, including plant height, root length, leaf area, and tiller number, thereby supporting sustainable rice production and promoting ecosystem balance. This study aims to assess the effects of natural farming on these traits, highlighting its potential for sustainable agriculture in comparison to the historically dominant chemical farming practices.

Materials and Methods

Study Area Experimental Details

As a part of pre immersion selection process for YRFs, a small-scale experiment was carried out in Kanumolu village, AP. This village belongs to the Krishna district which located in the coastal Andhra Region in Indian state of Andhra Pradesh. It is surrounded on the East by Bay of Bengal, West by Guntur, Bapatla and North by Eluru and NTR districts and South again by Bay of Bengal (Fig 1). The climatic conditions of this region consist of extremely hot summers and moderately hot winters and may be classified as tropical. The period starting from April to June is the hottest. The annual rainfall in the region is about 1047.68 mm and 66% of it is contributed to by the Southwest monsoon. Black cotton, sand clay loams and red loams and sandy soils observed in this region. The field survey was conducted during 8th September to 12th September, 2024. Farmer who's doing conventional farming for many years and who's adopted natural farming for 2st 3rd and 4th years were selected. Based on consultation with local ICRP people farmer's field were selected for small scale experiment. Fields were adjacent to each other so that error can minimize and same variety was sown in

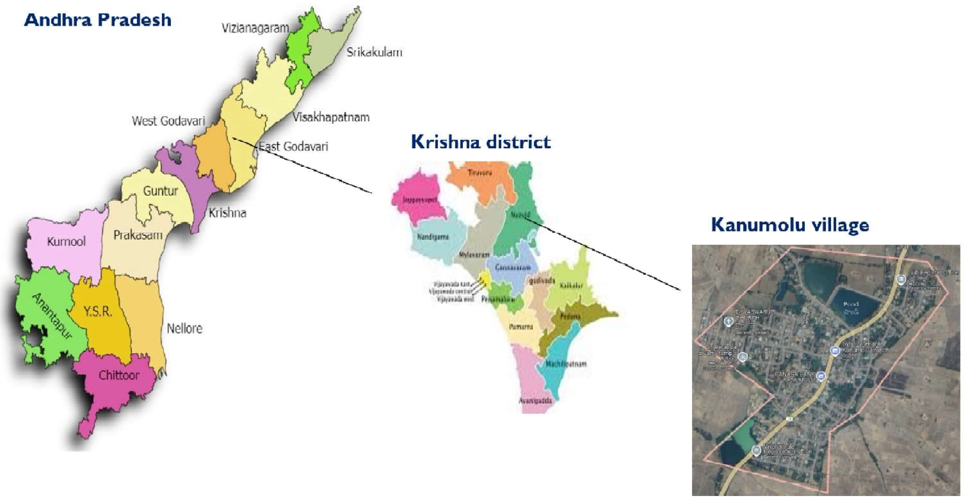

Fig 1: Study area considered for small scale experiment

each field (MTU 1061). Those farmers who follows the nine principles of natural farming given by APCNF were considered NF-adopters for two, three and four years, while NF-non-adopter considered as conventional farming.

Experimental Design

The experiment was conducted using a randomized block design (RBD). Four treatments were considered such as T1 (NF-adopters two years), T2 (NF-adopted for three years), T3 (NF-adopted for four years) and T4 (Conventional farming) with six replications per treatment for each measurement However, MTU 1061 variety was sown in both type of cropping system.

Measurement of Morphological and Physiological Attributes

Regarding the morphological observations, six plants were randomly selected in each treatment plot. The following observations were recorded at 30 days after planting (DAP). Plant population/m^2 at 30 DAP was recorded from three randomly selected places from each treatment. Plant height was recorded randomly selected six plants in each plot. The height was recorded in centimetre from ground level to uppermost leaf tip of main axis of the plant. The number of tillers on the six randomly selected plants was recorded and then the average number of tillers per plant was calculated and expressed in tillers $plant^{-1}$. The Number of green leaves on the six randomly selected plants was recorded and then the average number of leaves per plant was calculated. Normalized difference vegetation index (NDVI) was measured using a handheld Green Seeker device (Green Seeker®, Trimble, Westminster, CO, USA)) for efficient and convenient assessment. Leaf thickness was measured by using leaf thickness gauge and expressed in mm. Leaf area per plant (dm^2) was calculated with the help of formula given by Tsunoda (1964).

Leaf area = Length of the leaf × Breath of the leaf × Correlation factor (0.725) × Number of leaves per plant

Statistical Analysis

The experiment conducted in a Randomized Block Design (RBD) with comprising 4 treatment combinations involved six replications per treatment for each parameter. Further, Tukey's test for multiple comparison was used to assess pair-wise significance among the various treatments at a 5% level of significance wherever ANOVA indicated significant effects. Data analysis was performed in RStudio (version 4.3.0). Pearson's correlation matrix was visualized using R package with correlations significant at $p < 0.05$.

Result and Discussion

As agriculture faces increasing challenges due to declining soil health, environmental degradation, and rising input costs, there is an urgent need to explore sustainable farming practices that can maintain or improve productivity while reducing negative ecological impacts. In India, the reliance on chemical farming has led to issues such as soil depletion, water contamination, and reduced biodiversity, which threaten long-term agricultural sustainability. In this context, Zero Budget Natural Farming (ZBNF) offers a promising alternative that aims to reduce farmers' dependency on costly inputs while improving the health of agroecosystems. The shift from conventional chemical farming to natural farming practices is gaining traction, especially in Andhra Pradesh, where the government has actively promoted Andhra Pradesh Community Managed Natural Farming (APCNF). While many farmers have adopted ZBNF, there is still limited empirical evidence regarding its impact on crop performance and farm productivity in different regions. Specifically, little is known about the morpho-physiological responses of key crops like paddy to these alternative farming systems.

Morphological and Physiological Study

The different cropping systems had significant impact on morpho and physiological parameters of paddy. Conventional farming had the highest plant population (200.00 plants/m^2), followed by NF adopted for four years (189.26 plants/m^2), NF adopted for three years (185.00 plants/m^2) and NF adopted for two years (178.00 plants/m^2). Result indicating a notable difference in plant population among the treatments (Fig 2). Similarly maximum plant height was observed in conventional farming (65.20 cm), followed by NF adopted for two years (60.50 cm), NF adopted for three years (58.53 cm) and minimum plant height was found in NF adopted for four years (52.09 cm) (Fig 3). Tripathi *et al.* (2018) found that farmers practicing

ZBNF in Andhra Pradesh experienced improvements in crop yield and better resistance to environmental stressors like drought and flooding. The decrease in plant height and tiller numbers in natural farming systems, as seen in the present study, could align with ZBNF's focus on enhancing root systems and soil structure rather than maximizing above-ground growth. NF adopted for four years recorded the longest root length (23.77 cm), which was greater than NF adopted for three years (22.20 cm), NF adopted for two years (18.75 cm) and shortest root length was recorded in conventional farming (19.208 cm) (Fig 3).

Kumar *et al.* (2020) demonstrated that root length in crops tends to increase under organic and natural farming systems due to enhanced soil biology and structure. The present

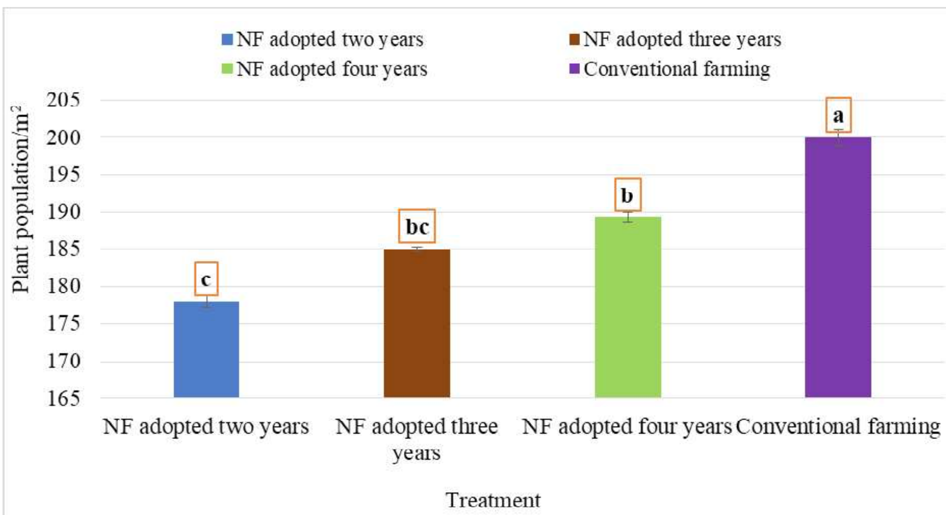

Fig. 2: Influence of different farming practices on plant population

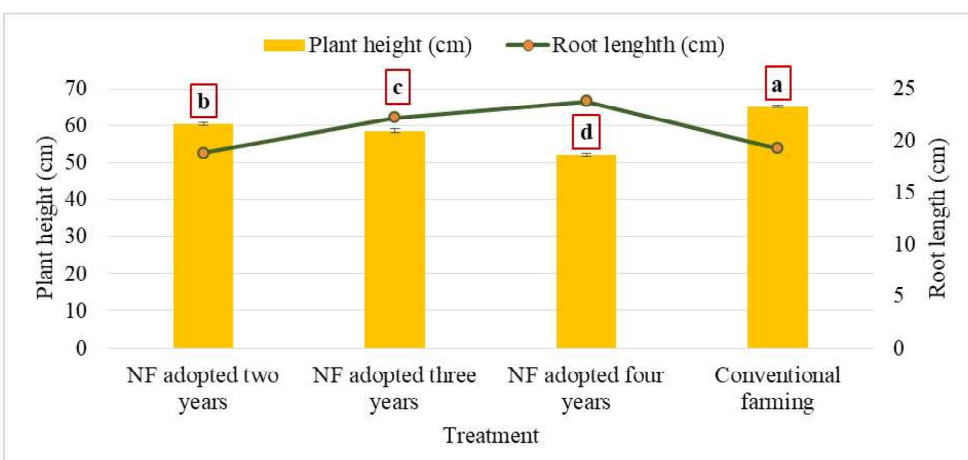

Fig. 3: Influence of different farming practices on plant height and root length

study's findings of longer root length in paddy under natural farming adopted for four years are consistent with this research, indicating better root proliferation as a potential advantage of natural farming. The highest number of tillers was recorded in NF adopted for four years (19.37) followed by NF adopted for three years (15.00), NF adopted for two years (13.29) whereas lowest was observed in conventional farming (11.26) (Fig 4). NF adopted for four years produced the highest number of leaves (88.99) with the number decreasing in NF adopted for three years (81.51), NF adopted for two years (75.00) whereas, lowest number of leaves were observed in conventional farming (68.99) (Fig 4).

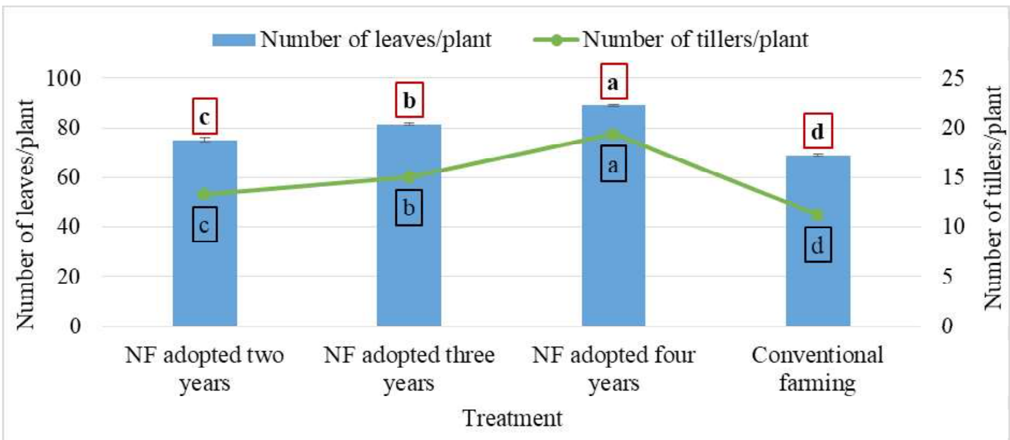

Fig. 4: Influence of different farming practices on number of leaves/plant and number of tillers/plants

Contrast to above results maximum leaf length were found in conventional farming (65.00 cm), followed by NF adopted for two years (62.26 cm), NF adopted for three years (57.17 cm) while NF adopted for four years (51.16 cm). NF adopted for four years had the widest leaves (1.21 cm), while NF adopted for two years had the narrowest leaves (0.70 cm), and NF adopted for three years had intermediate leaf width (0.90 cm) whereas conventional farming had average of 0.78 cm leaf width (Fig 5).

Similarly, maximum leaf area of paddy was observed in NF adopted for four years (3994.57 dm^2), followed by NF adopted for three years (3039.62 dm^2), conventional farming showed a slight increase (2536.54 dm^2) whereas, minimum leaf area was observed in NF adopted for two years (2363.91 dm^2) (Fig 6). Choudhary *et al.* (2018) found that leaf was greater in conventionally grown crops compared to organic systems, a pattern that mirrors the present study. The lower leaf area and narrower leaf width under natural farming may be due to reduced nutrient availability in the early years of adoption, but improvements in leaf thickness suggest an adaptive response to organic soil amendments over time. There was a considerable variation in NDVI between the treatments. NF adopted for four years recorded the highest NDVI (0.74) which was statistically at par with NF adopted for three years

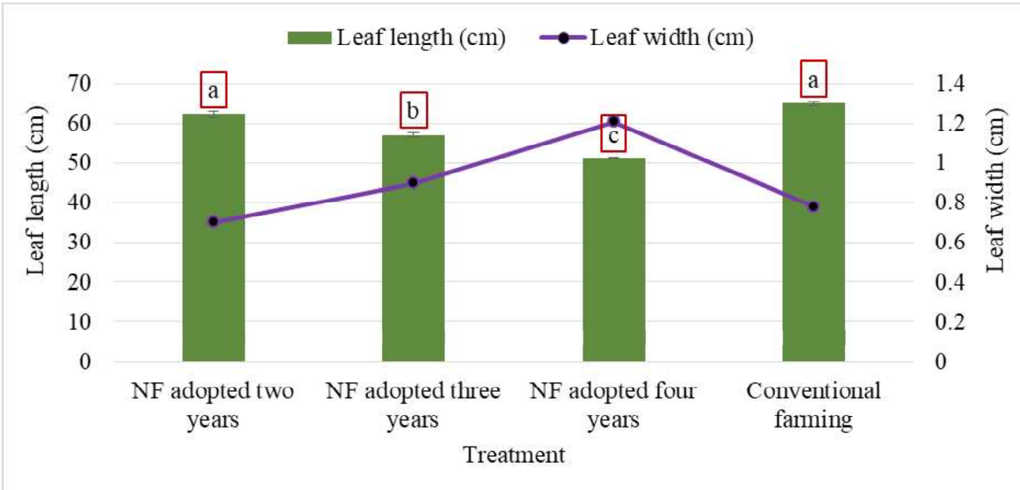

Fig. 5: Influence of different farming practices on leaf length and leaf width

(0.72), followed by NF adopted for two years (0.65) and lowest in conventional farming (0.59). Present results are contrast with Sharma *et al.* (2019) noted that NDVI values are often higher in conventional farming systems due to the lush canopy promoted by chemical fertilizers. Additionally, there was a significant difference in leaf thickness. The thickest leaves were observed in NF adopted for four years (0.69 mm) which was statistically at par with NF adopted for three years (0.65 mm), followed by NF adopted for two years (0.57 mm) and it was statistically at par with conventional farming (0.58 mm) (Fig 7).

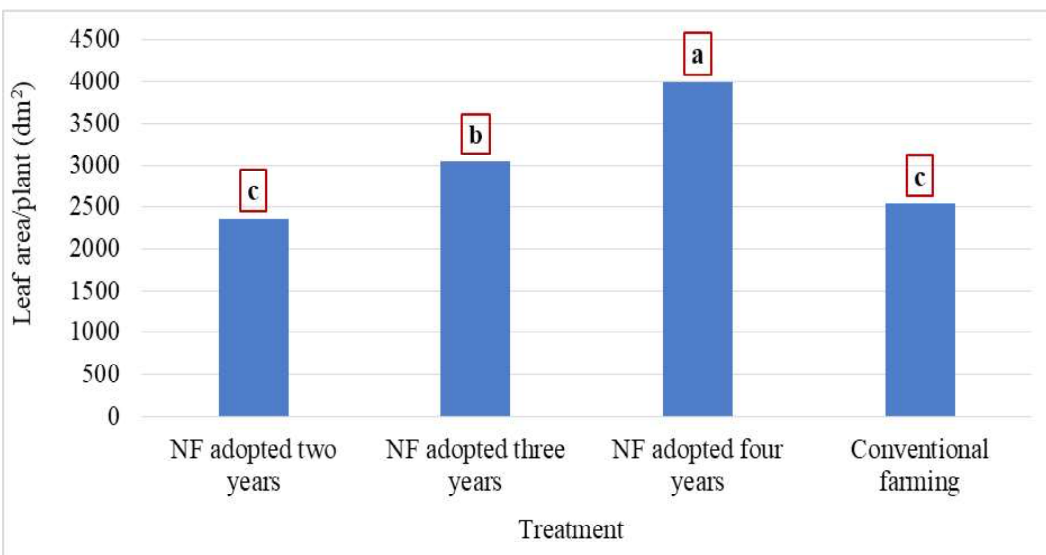

Fig. 6: Influence of different farming practices on leaf area of paddy

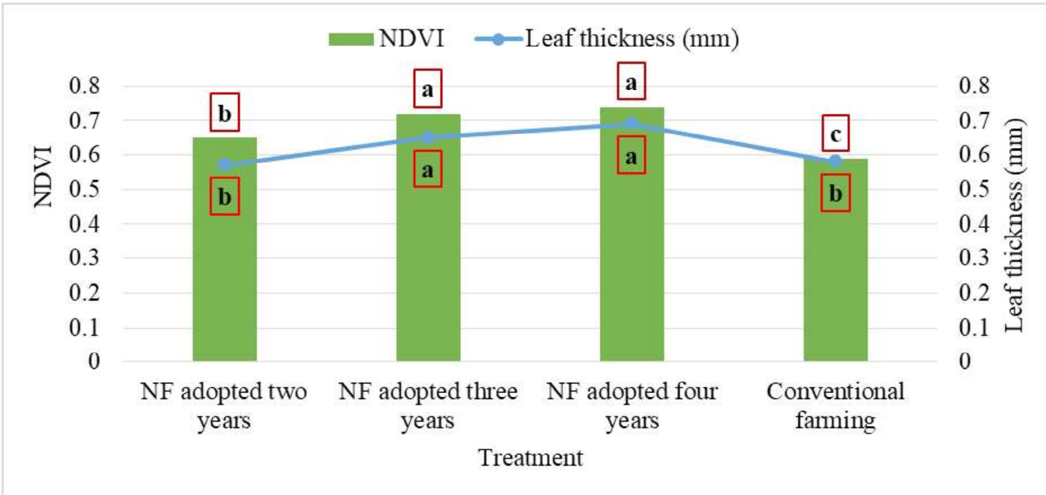

Fig. 7: Influence of different farming practices on NDVI and leaf thickness of paddy

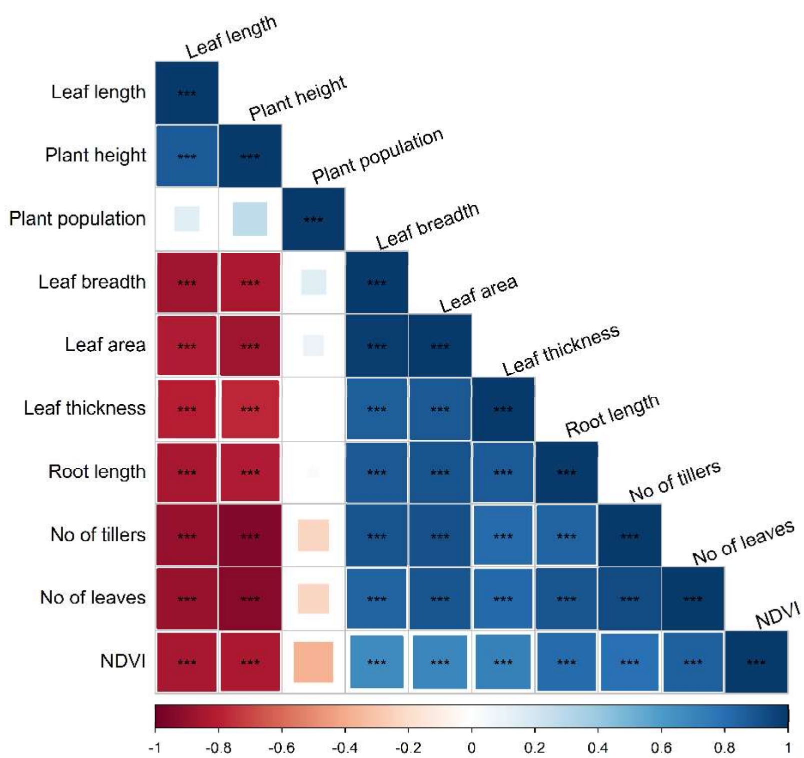

Fig. 8: Correlation matrix of different morpho-physiological parameters under the impact of different farming practices for paddy. (All the correlation coefficient values (r) are significant at 5% level of significance)

Correlation studies between different morpho-physiological parameters of paddy crop

The correlation matrix highlights important interactions between plant traits in paddy crops under different farming practices. Root length correlated highly with the number of tillers (0.85) and leaves (0.89), indicating a linkage between root development and above-ground growth. The number of tillers and leaves displayed a robust correlation (0.93), emphasizing their synchronous development. Positive correlations between in above parameters have better growth potential. Conversely, plant height was inversely related to root length (-0.83), the number of tillers (-0.95), and the number of leaves (-0.94), suggesting resource allocation trade-offs. Leaf length negatively correlated with tillers (-0.90) and leaves (-0.88), indicating potential competition in growth dynamics. NDVI had a negative correlation with plant height (-0.83) but was positively associated with root length (0.82), tillers (0.79), and leaves (0.85), linking canopy health to early root and shoot development. These insights help in understanding how different farming systems influence plant morphology and physiology, with significant implications for optimizing paddy growth in both conventional and natural farming systems. (Fig 8).

Conclusion

The study comparing conventional farming and Zero Budget Natural Farming (ZBNF) shows clear differences in their impact on paddy crop growth. conventional farming led to higher plant population, plant height, and leaf development, indicating its immediate advantages in promoting above-ground growth. However, this comes with environmental costs like soil degradation. On the other hand, ZBNF, especially after four years of adoption, demonstrated benefits such as longer roots and thicker leaves, suggesting improved root health and adaptation to organic practices. While NF adopted for four years had higher NDVI values due to denser canopies. In conclusion, while chemical farming offers short-term growth benefits, ZBNF presents a sustainable alternative with long-term advantages for soil health and ecological balance, making it a viable option for future agricultural practices. The observed morpho-physiological responses under natural farming conditions underscore the need for continued research and adaptation in farming practices to achieve a balance between productivity and sustainability.

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