AATCC Review

20 January 2025: Received
26 March 2025: Revised
21 April 2025: Accepted
25 April 2025: Available Online

https://aatcc.peerjournals.net/

Original Research Article
Open Access

Influence of Foliar Nano DAP Application with Moisture Conservation Strategies on Soil Moisture, Temperature, Canopy Temperature, and NDVI in *Rabi Maize* (*Zea mays* L.) under Eastern Rainfed Condition

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ABSTRACT

Currently, water hyacinth is a problematic weed, adversely affecting pond ecosystems and the environment. In eastern India, including Assam, water hyacinth (Eichhornia crassipes) is problematic, rendering water bodies like ponds and lakes unproductive due to its dominance. It can be effectively utilized as mulch in crop production. The field experiment was conducted at Assam Agriculture University, Jorhat, Assam during the period of 2022-23 and 2023-24 with the objective of evaluating the effect of different mulches and nutrient management practices on soil temperature, moisture conservation, SPAD, and NDVI values and canopy temperature of maize. The experiment was conducted in factorial RBD with 3 replications. There were three moisture conservation treatments viz., M_1:No-Mulching, M_2:Mulching with paddy straw @ 5.0 t/ha, M_3:Mulching with water hyacinth @ 5.0 t/ha and seven nutrient management practices viz., N_1:Recommended dose of fertilizer (60-40-40 kg/ha N-P_2O_5-K_2O), N_2:75% NP & 100% K with foliar spray of nano-DAP @2ml/l at knee high and tasselling stage, N_3:75% NP & 100% K with foliar spray of nano-DAP @4ml/l at knee high and tasseling stage, N_4:75% NP & 100% K with foliar spray of nano-DAP @6ml/l at knee high and tasseling stage, N_5:50 % NP & 100% K with foliar spray of Nano-DAP @2ml/l at knee hight and tasseling stage, N_6:50 % NP & 100% K with foliar spray of nano-DAP @4ml/l at knee high and tasseling stage and N_7:50 % NP & 100% K with foliar spray of nano-DAP @6ml /l at knee high and tasseling stage. The moisture content was recorded up to 30 cm depth (0-15 cm depth and 15-30 cm depth). The result revealed that all the treatments with mulching had higher soil temperature, higher soil moisture, and lower canopy temperature compared to no mulching treatment, but there was no significant effect of nutrient management practices on these parameters. Water hyacinth mulch treatment recorded the highest soil moisture at 10 cm depth and lower canopy temperature. The average soil moisture recorded was 17.95% under no mulch treatment and 20.27% by weight under water hyacinth mulching. Similarly, the average canopy temperature recorded was 24.18°C under no mulch treatment and under water hyacinth mulching it was 23.76°C and the soil temperature recorded was 19.30 °C under no mulch treatment and it was 20.02 °C under water hyacinth mulching. Normalized Difference Vegetation Index (NDVI) and SPAD values were significantly influenced by mulching compared to no mulching treatment, but there was no significant effect due to nutrient management practices. Water hyacinth mulch treatment recorded the highest NDVI, lower canopy temperature, and higher SPAD Values. The average NDVI recorded was 0.609 under no mulch treatment and 0.671 under water hyacinth mulching, the average canopy temperature recorded was 24.18°C under no mulch treatment and 23.76 °C under water hyacinth mulching and SPAD values were 34.58 under no mulching and 37.13 under water hyacinth mulching.

Keywords: *NANO-DAP;Soil temperature; Moisture conservation; SPAD; NDVI*

Introduction

Maize (*Zea mays* L.), commonly known as "corn" is one of the most cultivated worldwide cereal crops due to high genetic yield potentiality and wider adaptability to various climatic conditions. It functions as a fundamental food resource for billions of individuals and is utilized in multiple forms, ranging from whole grains to processed products and livestock feed. The crop's importance transcends human consumption; it is integral to global agriculture, supporting millions of farmers' livelihoods and contributing to nations' economic stability worldwide [1]. India is the fourth in area and seventh in production of maize globally, contributing 2% to the world's total maize production.

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DOI: https://doi.org/10.21276/AATCCReview.2025.13.02.362

In the 2022-23 period, maize was grown across 207 million hectares worldwide, producing over 1,218 million tons. The United States is the leading producer, responsible for nearly one-third of global maize production, followed by China, Brazil, the European Union, and Argentina. In India, maize is cultivated on 10.6 million hectares, yielding 38.0 million tons annually, with a productivity rate of 3,584 kg/ha. The major maize-producing states in India include Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh, Bihar, Telangana, Gujarat, Tamil Nadu, and Jammu & Kashmir. The growth in maize production in India can be attributed to advancements in high-yield maize hybrids and enhanced agronomic practices [2]. The global maize industry confronts various challenges, notably climate change, which alters weather patterns and heightens the occurrence of extreme weather events. In addition, pests and diseases present substantial risks to maize production, adversely affecting both yield and quality. However, there are emerging opportunities driven by technological innovations, such as genetically modified varieties and enhanced agricultural practices, designed to improve productivity and resilience in climatic variability conditions [3]. Currently, India is primarily concentrating on expanding maize cultivation, especially during the rainy (*Kharif*) and winter (*Rabi*) seasons, in order to address significant production shortfalls. But in light of the current global and Indian agricultural challenges, it is essential to explore new innovative farming practices that ensure greener and more sustainable food production, while safeguarding the nation's long-term food security and nutritional needs. Nanofertilizers have emerged as a promising solution to tackle agricultural challenges, offering improved efficiency and reduced environmental impact. They can be categorized based on their mode of action, nutrient composition, and formulation. In recent years the Government of India has recommended Nano DAP liquid fertilizer, which is more affordable and biologically safe, aiming to reduce soil, water, and air pollution. Nano-fertilizers, synthesized from traditional fertilizers, bulk materials, or extracted from different vegetative or reproductive parts of plants using nanotechnology, enhance soil fertility, productivity, and the quality of agricultural produce. They are non-toxic, less harmful to the environment and humans, and reduce costs while maximizing profits [4]. Nano DAP contains nanoparticles of Diammonium Phosphate (DAP), which provide nitrogen and phosphorus essential for crop growth and development. It supports sustainable agriculture by improving nutrient availability and uptake. Nano-fertilizers, such as nano DAP, can enhance nutrient uptake and support sustainable farming practices [5]. Modern agriculture relies heavily on agro-chemicals, but these have not significantly improved plant nutrient use efficiency (NUE) and crop productivity. Nanoscience and nanotechnology present a new frontier for researchers with nano-fertilizers, offering hope for enhancing agricultural productivity.

Maize can be cultivated throughout the year, but during the rabi season, low rainfall causes moisture stress. This issue can be mitigated by applying mulch, a material layer placed on the soil surface. The main purposes of mulch are conserving soil moisture, improving soil fertility and health, and reducing weed growth. Mulching acts as a barrier by reducing evaporation retaining moisture and preventing the loss of moisture from the soil. In India, approximately 20 million hectares of land are mulched [6]. Mulch helps reduce soil erosion by shielding the soil surface from raindrop impact and preventing soil crust formation. As the mulch decomposes, it provides essential nutrients to plants. Additionally, applying mulch increases the infiltration of runoff or irrigation water and minimizes evaporation losses. This practice also improves the water use efficiency of crops [7]. Mulching is an important practice in agricultural production, involving the use of materials that can be either organic, such as paddy straw, or non-organic, like plastic. Mulches are used in both commercial crop production and gardening, and when applied correctly, they can enhance soil productivity. Using eco-friendly, biodegradable mulch layers instead of common plastic ones can increase crop yields, reduce agricultural water consumption, and address residual film pollution issues. Mulching is a promising alternative that supports the sustainable development of agriculture. In eastern India, including Assam, water hyacinth (*Eichhorniacrassipes*) is a problematic weed, rendering water bodies like ponds and lakes unproductive due to its dominance. This plant has become an environmental and social menace in many of the country's water bodies [8]. Under the situations, water hyacinth can be very well recycled as mulch material for crop production.

Normalized Difference Vegetation Index (NDVI) is a remote sensing tool used to assess vegetation health by measuring the difference between near-infrared (strongly reflected by vegetation) and visible red light (absorbed by vegetation). It offers insights into plant vigor, biomass, and stress levels, with values ranging from -1 to +1. This index is widely applied in agriculture, forestry, and ecological research to monitor vegetation dynamics and environmental changes [9]. The Green Seeker is an advanced handheld sensor that leverages NDVI technology to provide on-the-spot assessments of crop health and vigor. By emitting red and infrared light and analyzing the reflected wavelengths, it calculates NDVI values. It helps farmers optimize fertilizer usage, enhance crop productivity, and adopt precision agriculture practices by offering accurate data for decision-making. Several researchers have used Green Seeker NDVI equipment in fertilizer management and yield forecasting tools—reporting a significant positive relationship between NDVI and crop N demand [10], biomass prediction [10] and grain yield prediction [11]. This shows the usefulness of the tool in nutrient management and yield forecasting. Canopy temperature refers to the temperature of plant leaves, often measured using infrared thermometers or sensors. It is an essential indicator of plant stress, particularly under water-deficit conditions. Higher canopy temperatures usually signify reduced transpiration due to water stress, whereas cooler canopy temperatures indicate healthy water uptake and cooling through transpiration. Monitoring canopy temperature is crucial in agricultural research for assessing drought tolerance and irrigation management. Considering the aforementioned factors, studies were carried out to evaluate the impact of moisture conservation and nutrient management practices on soil temperature, moisture retention, canopy temperature, NDVI, and Green Seeker values in maize crops.

Materials and Methods

Experimental site

The experiment was carried out on sandy loam soil at the Instructional cum Research (ICR) Farm of Assam Agricultural University, situated in Borbheta, approximately 4 km from Jorhat town. Geographically, Jorhat is located at 26° 47'N latitude, 94°12'E longitude, and at an altitude of 86.6 m above the mean sea level. The experimental site falls into sub-tropical humid having a hot and humid summer and a relatively dry cold winter. Monsoon rain in this region generally starts from the month of June and continues up to the month of September-October with the pre-monsoon showers from mid-March to April. The intensity of rainfall decreases from the middle of October, reaching a minimum from December to January. The humidity of this zone is high (above 80%) during the kharif season at the region is located in a sub-tropical humid region. The maximum temperature range is 34-37˚C during summer and the minimum temperature ranges from 8-10 ˚C during winter. The weekly average maximum temperature during the crop growing phase (44th SMW of 2022 to 11th SMW of 2023) ranged from 21.4°C (3rd SMW of 2023) to 29.3°C (10th SMW of 2023) and the minimum temperature during the same period ranged from 7.9°C (7th SMW of 2023) to 15.7°C (11th SMW of 2023) respectively. The total amount of rainfall received during the entire experiment was 224.6 mm (44th SMW of 2022 to 11th SMW of 2023) with four (15) rainy days. The corresponding values of mean weekly maximum temperature during the crop growing phase (44th SWM in 2023 to 12th SWM in 2024) of the second year, ranged from 21.7°C to 31.3°C while the mean weekly minimum temperature varied between 8.1°C to 17.4°C, respectively. The total amount of rainfall received during the entire experiment was 101.6 mm (44th SMW of 2023 to 12th SMW of 2024) on 11 rainy days. The field capacity and permeant wilting point of the experimental plot were supposed to be 24.60 and 9.48% by weight.

Initial Soil Properties

Before the experiment, the soil at the experimental site was analyzed to determine its various properties. The soil was classified as sandy loam in texture, with an acidic pH of 5.23 and 5.25. The organic carbon content was medium, at 0.67% and 0.65%. The available nitrogen levels were medium (245.1 and 245.9 kg/ha), available phosphorus was high (18.22 and 19.22 kg/ha), and available potassium was medium (184.3 and 186.3 kg/ha).

Treatments and Experimental Design

The experiment was laid out in a factorial randomized block design with 3 replications. The treatment consisted of threemoisture conservation treatments viz., M_1:No-Mulching, M_2:Mulching with paddy straw @ 5.0 t/ha, M_3:Mulching with water hyacinth @ 5.0 t/ha, and seven nutrient management practices viz., N_1:Recommended dose of fertilizer (60-40-40 kg/ha N-P_2O_5-K_2O), N_2:75% NP & 100% K with foliar spray of nano-DAP @2ml/l at knee high and tasselling stage, N_3:75% NP & 100% K with foliar spray of nano-DAP @4ml/l at knee high and tasselling stage, N_4:75% NP & 100% K with foliar spray of nano-DAP @6ml/l at knee high and tasselling stage, N_5:50 % NP & 100% K with foliar spray of Nano-DAP @2ml/l at knee high and tasselling stage, N_6:50 % NP & 100% K with foliar spray of nano-DAP @4ml/l at knee high and tasselling stage and N_7:50 % NP & 100% K with foliar spray of nano-DAP @6ml /l at knee high and tasselling stage.

Canopy temperature (°C), SPAD and NDVI values

Canopy temperature

Plant physiological activity is determined by measuring canopy temperature, which can also be used to track plant development. Temperature was measured remotely using an infrared thermometer.

SPAD Values

Soil Plant Analysis Development (SPAD) is used to measure the amount of chlorophyll in plant leaves. An MC-100 chlorophyll concentration meter was used to quantify SPAD. Over 120 days, readings were obtained from the top three fully formed leaves on each plot at 30-day intervals at 30, 60, 90, and 120 DAS. For every leaf, three SPAD readings were obtained: two at the midpoint of the leaf blade and one from a distance of three centimeters. These three readings were then averaged to determine the leaf's mean SPAD value.

Normalized Difference Vegetation Index (NDVI)

A green seeker at different developmental stages was used to obtain the Normalized Difference Vegetation Index; it operates on the basis of NDVI principles and shows values ranging from 0.01 to 0.99. Each plot had three readings, and the average was determined.

Normalized Difference Vegetative Index (NDVI) = NIR – RED NIR + RED In which NIR stands for near-infrared spectrum

RED = Red range of the spectrum

Results and Discussion

Soil Studies

Soil temperature (°C): Under mulching practices, the soil temperature between mulched treatment i.e. water hyacinth and paddy straw mulch were significantly higher than the un-mulched plots. The higher soil temperature was noticed in mulching plot water hyacinth @5t/ha and paddy straw mulching @5t/ha during different growth stages of the crop period. The soil temperature was high in water hyacinth mulching @5t/ha whereas under no mulching treatment soil temperature was found to be minimum. A similar trend was found in the corresponding year also. There were minimum soil temperature fluctuations under mulch during daily cycle, as well as the comparatively elevated soil temperatures observed beneath water hyacinth @5t/ha (M_3) and paddy straw @5t/ha (M_2) given in Table 1. [12] indicated the attainment of higher and more stable soil temperatures in winter conditions under mulch. The preservation of maximum soil temperatures by non-mulched soils during peak sunlight exposure was readily apparent due to their pronounced capacity for absorption and reflection, respectively. The maintenance of relatively elevated soil temperatures during the late night to early morning hours under the water hyacinth and rice straw mulches was significantly obscured by their insulating properties, which effectively inhibited temperature inversion from the soil surface. The attenuation of mulch effects on temperature fluxes in the later stages of plant growth can be primarily attributed to the complete coverage provided by the crop canopy, which facilitated mutual shading of the soil surface.

Soil moisture: The water hyacinth and rice straw mulches effectively retained a greater amount of water in the topsoil and the least in the control during the dryland period of plant growth (30 to 120 DAS) (Table 2). There was a shower after 90 DAS minimized the differences in the level of water content among the mulch and un-mulched plots in 2022-23.However a moderate shower throughout the crop growing period created the differences in the level of water content among the mulch and un-mulched plots in the corresponding year.

Mulched plots had higher soil moisture content throughout the growing season than the un-mulched plots for 0-15 cm depth. Notably, a considerably greater level of moisture was retained under water hyacinth mulching @5t/ha in both the years of experimentation. There was 7.4 and 9.8%, 10.8 and 8.3%, 23.9 and 21.16% and 13.79 and 15.22% higher moisture content in water hyacinth mulched @5t/ha plot over un-mulched plot during 2022-23 and 2023-24, at 30, 60, 90 and 120 DAS, respectively. The minimum moisture content was recorded in the plots devoid of mulching materials, it is because the application of mulching materials significantly diminished the quantity of energy expended during the evaporation process by obstructing the efflux of water vapor from the soil, thereby facilitating the conservation of soil moisture levels. The retention of elevated moisture levels beneath mulches is a widely acknowledged phenomenon, and the current observation aligns with this established principle and the results reported [12]. Water hyacinth may be considered as one of the best among the various organic mulches as it is easy to collect and is considered as one of the best mulching material, particularly in crops like banana, potato, lemon.

Table 1. Effect of moisture conservation and nutrient management practices on soil temperature (°C) at different growth stages in maize

Treatment	30 DAS		60DAS		90 DAS		120 DAS	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
Moisture conservation practices (M)								
M_1	20.28	21.78	14.70	17.20	17.02	18.02	23.06	22.31
M_2	20.79	22.29	14.99	17.49	17.30	18.26	23.20	22.45
M_3	20.94	22.44	15.69	18.19	18.10	19.10	23.24	22.49
SEm (±)	0.09	0.07	0.12	0.07	0.09	0.07	0.11	0.07
CD (P=0.05)	0.25	0.19	0.34	0.20	0.25	0.19	0.31	NS
Nutrient management (N)								
N_1	20.96	22.46	15.21	17.71	17.60	18.60	23.28	22.53
N_2	20.67	22.17	15.09	17.59	17.40	18.40	23.11	22.41
N_3	20.72	22.22	15.11	17.61	17.54	18.54	23.16	22.41
N_4	20.60	22.10	15.36	17.86	17.60	18.60	23.30	22.55
N_5	20.64	22.14	15.01	17.51	17.31	18.31	23.09	22.34
N_6	20.50	22.00	15.03	17.53	17.39	18.36	23.09	22.34
N_7	20.60	22.10	15.09	17.59	17.47	18.39	23.16	22.36
SEm (±)	0.13	0.13	0.10	0.10	0.18	0.17	0.10	0.10
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

M_1: No mulching, M_2: Paddy straw mulch @ 5t/ha, M_3: Water hyacinth mulch@ 5t/ha
N_1: Recommended dose of fertilizer, N_2: 75% NP & 100% K + nano-DAP 2 ml/l, N_3:75% NP &100% K + nano-DAP 4ml/l*, N_4:75% NP &100% K + nano-DAP 6ml/l*, N_5:50 % NP & 100% K + nano-DAP 2 ml/l *, N_6:50% NP & 100% K + nano-DAP 4ml/l*, N_7:50 % NP &100% K+ nano-DAP 6ml/l* @ Foliar application at different stage * Knee high stage, Tasseling stage*

Table 2. Effect of moisture conservation and nutrient management practices on soil moisture content (%) at 0-15 cm depth at different growth stages in maize

Treatment	30 DAS		60DAS		90 DAS		120 DAS	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
Moisture conservation practices (M)								
M_1	21.13	20.08	17.92	21.83	12.97	14.65	17.32	17.67
M_2	22.21	21.28	18.56	22.94	15.21	16.77	18.85	19.79
M_3	22.71	22.05	19.87	23.65	16.07	17.75	19.71	20.36
SEm (±)	0.42	0.29	0.19	0.31	0.17	0.17	0.34	0.18
CD (P=0.05)	1.21	0.84	0.55	0.87	0.49	0.50	0.97	0.52
Nutrient management (N)								
N_1	22.18	21.76	19.44	21.89	14.85	16.44	19.02	19.24
N_2	22.01	21.14	18.55	22.89	14.72	16.35	18.58	19.37
N_3	22.09	21.20	18.57	22.84	14.82	16.09	18.87	19.11
N_4	22.13	21.71	19.46	23.17	14.97	16.63	19.22	19.43
N_5	21.83	20.90	18.44	22.73	14.52	16.31	18.09	19.15
N_6	22.69	22.71	18.52	23.46	14.64	16.24	19.22	19.03
N_7	22.71	21.90	18.50	22.65	14.70	16.69	18.26	19.60
SEm (±)	0.65	0.45	0.29	0.47	0.26	0.27	0.52	0.28
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

M_1: No mulching, M_2: Paddy straw mulch @ 5t/ha, M_3: Water hyacinth mulch@ 5t/ha
N_1: Recommended dose of fertilizer, N_2: 75% NP & 100% K + nano-DAP 2 ml/l, N_3:75% NP &100% K + nano-DAP 4ml/l*, N_4:75% NP &100% K + nano-DAP 6ml/l*, N_5:50 % NP & 100% K + nano-DAP 2 ml/l *, N_6:50% NP & 100% K + nano-DAP 4ml/l*, N_7:50 % NP &100% K + nano-DAP 6ml/l* @ Foliar application at different stage * Knee high stage, Tasseling stage*

Plant studies

SPAD Values: In all the dates water hyacinth mulching @ 5 t/ha (M_3) registered the highest values of SPAD and was followed by paddy straw mulch @ 5 t/ha (M_2) and un-mulched (M_1) plots. However, significant variation was observed at 30 DAS only. The favorable reaction of chlorophyll concentration during the initial phase of plant development may be ascribed to the presence of nutrients in adequate quantities essential for chlorophyll synthesis. Furthermore, nitrogen constitutes a fundamental element of all amino acids present in proteins and lipids, which serve as structural components of the chloroplast. The retention of moisture attributable to mulching further enhanced the availability of nitrogen. Conversely, the scarcity of both moisture and nitrogen in the control plots adversely influenced the chlorophyll levels within the plants as reported [13].Where the effect of nutrient management practices with foliar application of nano DAP did not result in any significant effect on SPAD values recorded at 30-day intervals except at 90 DAS during 2023-24. Application of 75% NP + nano-DAP 6ml/l (N_4) registered the highest SPAD values in all the dates except at 30 DAS and remained at par with RDF (N_1) and 75 % NP & 100 % K + nano-DAP 2-4 ml/l (N_2& N_3). At 30 DAS, however, the SPAD values were highest in plots applied with RDF (N_1). The augmentation of SPAD values demonstrated a noteworthy enhancement in nitrate reductase activity, while the protein and chlorophyll concentrations were directly correlated with SPAD values across various nitrogen application levels.

The linear and positive correlation between SPAD values and leaf nitrogen percentage suggested a reliance of SPAD values on the nitrogen content within the leaf during the flowering stage [14]. [15] reported that nano fertilizers facilitate the availability of essential nutrients to the developing plant by promoting rapid nutrient absorption via the stomatal openings of leaves. This mechanism may have led to an enhancement in chlorophyll synthesis, an increase in the photosynthetic rate, greater accumulation of dry matter, improved enzymatic activity, and enhanced auxin metabolism within the plant, culminating in increased height of the plants.

Table 3. Effect of moisture conservation and nutrient management practices on SPAD values at different growth stages of maize

Treatment	30 DAS		60DAS		90 DAS		120 DAS	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
M_1	28.97	29.93	36.96	37.70	40.17	41.09	30.30	31.54
M_2	31.64	32.84	37.81	38.49	41.49	42.82	31.65	32.65
M_3	32.78	33.93	38.64	39.66	42.47	43.65	32.48	33.39
SEm (±)	0.59	0.56	1.11	1.06	1.26	1.00	1.01	0.94
CD (P=0.05)	1.68	1.59	NS	NS	NS	NS	NS	NS
Nutrient management (N)								
N_1	32.56	33.64	40.09	40.94	43.53	44.82	34.10	34.34
N_2	31.33	32.53	38.81	38.55	42.67	42.76	31.91	32.84
N_3	31.74	32.94	39.23	39.64	41.72	43.91	32.15	33.15
N_4	32.47	33.44	41.20	41.94	44.65	45.68	33.24	34.48
N_5	29.29	30.49	34.47	35.20	37.78	38.37	28.48	29.72
N_6	29.66	30.63	35.57	36.97	38.50	39.09	29.71	30.73
N_7	30.86	31.94	36.37	37.10	39.88	40.14	30.76	31.45
SEm (±)	0.90	0.85	1.76	1.61	1.95	1.53	1.54	1.44
CD (P=0.05)	NS	NS	NS	NS	NS	4.38	NS	NS

M_1: No mulching, M_2: Paddy straw mulch @ 5t/ha, M_3: Water hyacinth mulch@ 5t/ha
N_1: Recommended dose of fertilizer, N_2: 75% NP & 100% K + nano-DAP 2 ml/l, N_3:75% NP &100% K + nano-DAP 4ml/l*, N_4:75% NP &100% K + nano-DAP 6ml/l*, N_5:50 % NP & 100% K + nano-DAP 2 ml/l *, N_6:50% NP & 100% K + nano-DAP 4ml/l*, N_7:50 % NP &100% K + nano-DAP 6ml/l* @ Foliar application at different stage * Knee high stage, Tasseling stage.*

Normalized Difference Vegetation Index (NDVI): The application of mulch was found to be more significant than no mulch plot. Here, water hyacinth (M_3) contributed to an augmentation of the Normalized Difference Vegetation Index (NDVI) or the chlorophyll concentration within the foliar structures, demonstrating comparable efficacy to that of paddy straw mulching @5t/ha (M_2). A notable influence was exerted on nitrogen transformation processes through the alteration of the thermal regime of the soil under mulching conditions, specifically with regard to both water hyacinth @5t/ha and paddy straw mulch @5t/ha, attributable to the gradual mineralization of organic nitrogen, which resulted in an enhancement of the mineral nitrogen content within the soil (including both nitrate and ammonium forms). Consequently, this phenomenon mitigated the impacts of nitrogen deficiency while simultaneously promoting an increase in chlorophyll content, as elucidated [16]. Under nutrient management there was no significant difference between the treatments but recommended dose of fertilizer (N_1) was found to be at par with 75% NP &100% K + nano-DAP 6ml/l(N_4),75% NP &100% K + nano-DAP 4ml/l(N_3), 75% NP & 100% K + nano-DAP 2 ml/l (N_2) was at par with each other at 30DAS. AT 75% NP &100% K + nano-DAP 6ml/l (N_4) had a higher normalized difference vegetation index with was at par with a Recommended dose of fertilizer(N_1),75% NP &100% K + nano-DAP 4ml/l(N_3), 75% NP & 100% K + nano-DAP 2 ml/l(N_2).

Table 4. Effect of moisture conservation and nutrient management practices on NDVI valueat different growth stage of maize

Treatment	30 DAS		60DAS		90 DAS		120 DAS	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
M_1	0.31	0.32	0.70	0.72	0.79	0.81	0.60	0.62
M_2	0.35	0.36	0.75	0.77	0.83	0.84	0.63	0.64
M_3	0.38	0.39	0.77	0.79	0.86	0.86	0.66	0.66
SEm (±)	0.016	0.016	0.017	0.015	0.012	0.011	0.015	0.013
CD (P=0.05)	0.045	0.046	0.048	0.042	0.034	0.031	NS	NS
Nutrient management (N)								
N_1	0.40	0.40	0.75	0.78	0.84	0.85	0.65	0.66
N_2	0.34	0.36	0.74	0.76	0.82	0.82	0.64	0.64
N_3	0.36	0.37	0.73	0.77	0.83	0.84	0.63	0.65
N_4	0.36	0.38	0.79	0.82	0.85	0.86	0.66	0.67
N_5	0.31	0.33	0.71	0.72	0.79	0.80	0.60	0.61
N_6	0.33	0.34	0.72	0.74	0.80	0.81	0.61	0.62
N_7	0.33	0.35	0.73	0.75	0.81	0.82	0.63	0.63
SEm (±)	0.024	0.025	0.026	0.022	0.018	0.016	0.023	0.020
CD (P=0.05)	NS	NS	NS	NS	0.051	0.047	NS	NS

M_1: No mulching, M_2: Paddy straw mulch @ 5t/ha, M_3: Water hyacinth mulch@ 5t/ha
N_1: Recommended dose of fertilizer, N_2: 75% NP & 100% K + nano-DAP 2 ml/l, N_3:75% NP &100% K + nano-DAP 4ml/l*, N_4:75% NP &100% K + nano-DAP 6ml/l*, N_5:50 % NP & 100% K + nano-DAP 2 ml/l *, N_6:50% NP & 100% K + nano-DAP 4ml/l*, N_7:50 % NP &100% K + nano-DAP 6ml/l* @ Foliar application at different stage * Knee high stage, Tasseling stage*

Canopy temperature (°C): The effects of mulching practices on canopy temperature were found to be non-significant throughout the crop growing period of maize during both the years of investigation. However, the minimum canopy temperature was recorded with water hyacinth mulching (M_3) throughout the temporal phases of the investigation and was followed by paddy straw mulching (M_2) and un-mulched plots (M_1). The canopy temperature is contingent upon both soil moisture levels and the hydric status of the plant, the application of mulch effectively preserved soil moisture, thereby augmenting the water availability for the plant's transpiration processes, which subsequently led to a reduction in canopy temperature as a secondary effect. The implementation of the water harvesting (M_3) technique facilitated an increase in soil moisture, resulting in a more pronounced decrease in canopy temperature. The observed escalation in canopy temperature with the advancement of growth can be attributed to the senescence of the canopy leaves leading to reduced transpiration capacity as compared to that of younger leaves [17]. There was no significant effect of the nutrient management treatment on canopy temperature during both years of study. However, there was no significant difference in canopy temperature under nutrient management there was no significant difference between the treatments. 75% NP &100% K + nano-DAP 6ml/l was at par with a recommended dose of fertilizer,75% NP &100% K + nano-DAP 4ml/l, 75% NP & 100% K + nano-DAP 2 ml/l.

Table 5. Effect of moisture conservation and nutrient management practices on canopy temperature (°C) at different growth stage of maize

Treatment	30 DAS			60DAS			90 DAS			120 DAS		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
Moisture conservation practices (M)												
M_1	24.42	24.41	24.41	23.92	25.12	24.94	22.42	21.31	21.86	25.66	26.20	25.93
M_2	24.10	24.17	24.13	23.50	24.70	24.52	22.00	21.07	21.54	25.60	26.16	25.88
M_3	24.00	23.94	23.97	23.34	24.54	24.10	21.84	20.82	21.34	25.53	26.10	25.81
SEm (±)	0.18	0.16	0.17	0.19	0.20	0.19	0.19	0.16	0.17	0.10	0.10	0.10
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Nutrient management (N)												
N_1	23.91	23.93	23.98	23.28	22.28	23.88	21.78	20.83	21.36	25.42	25.99	25.71
N_2	24.14	24.05	24.07	23.53	22.39	24.19	22.09	20.95	21.49	25.61	26.18	25.89
N_3	24.03	23.99	23.88	23.59	22.45	24.13	22.03	20.89	21.43	25.49	26.06	25.90
N_4	23.88	23.88	23.97	23.27	22.33	23.87	21.77	20.78	21.27	25.41	25.98	25.77
N_5	24.52	24.74	24.63	23.91	23.14	24.51	22.41	21.64	22.03	25.88	26.44	26.16
N_6	24.41	24.33	24.36	23.91	22.73	24.51	22.41	21.23	21.81	25.69	26.26	25.97
N_7	24.33	24.31	24.33	23.61	22.71	24.21	22.11	21.21	21.67	25.62	26.18	25.69
SEm (±)	0.27	0.25	0.26	0.29	0.25	0.27	0.29	0.25	0.27	0.15	0.16	0.14
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

M_1: No mulching, M_2: Paddy straw mulch @ 5t/ha, M_3: Water hyacinth mulch@ 5t/ha
N_1: Recommended dose of fertilizer, N_2: 75% NP & 100% K + nano-DAP 2 ml/l, N_3:75% NP &100% K + nano-DAP 4ml/l*, N_4:75% NP &100% K + nano-DAP 6ml/l*, N_5:50 % NP & 100% K + nano-DAP 2 ml/l *, N_6:50% NP & 100% K + nano-DAP 4ml/l*, N_7:50 % NP &100% K + nano-DAP 6ml/l* @ Foliar application at different stage * Knee high stage, Tasseling stage*

Future scope

Currently, water hyacinth is a problematic weed, adversely affecting pond ecosystems and the environment. With a rapid growth rate (44-106 t dry matter/ha/yr), water hyacinth causes significant harm, adversely impacting water resources, fisheries, irrigation, drainage canals, and public health. In eastern India, including Assam, water hyacinth (*Eichhornia crassipes*) is problematic, rendering water bodies like ponds and lakes unproductive due to its dominance. This plant has become an environmental and social menace in many of the country's water bodies. Water hyacinth, typically seen as waste, needs proper recycling. It can be productively used as mulch in crop production and can be used as manure and mulch in many crops. This can serve as renewable energy.There is ample scope of using this waste as wealth by proper recycling in crop production and building entrepreneurship.

Conclusion

Among the different mulch materials, water hyacinth mulching showed the highest moisture conservation and soil temperature regulation, followed by paddy straw mulching. Soil moisture conservation practices significantly influenced the Normalized Difference Vegetation Index (NDVI), canopy temperature (°C), and SPAD values. Canopy temperature was lower in mulched plots, especially with water hyacinth mulching, followed by paddy straw mulching. However, there was no significant difference in the effects of nutrient management practices. In contrast, non-mulched plots experienced higher soil evaporation and greater heat absorption, leading to elevated canopy temperatures. NDVI, which measures vegetation health by analyzing the difference between near-infrared light (reflected by vegetation) and red light (absorbed by vegetation), was higher under mulching. This is because mulching helps retain soil moisture, regulate temperature, and reduce plant stress, promoting healthier and denser vegetation. As a result, NDVI values were higher in mulched plots. Similarly, SPAD values, which indicate chlorophyll content in leaves, were higher under mulching, reflecting better photosynthetic activity and overall plant health. Mulching reduced water evaporation and maintained consistent soil moisture, ensuring better nutrient uptake and less plant stress. This contributed to higher chlorophyll content and, consequently, higher SPAD values.

Conflict of interest

We state that there is no conflict of interest in publishing this article.

Acknowlegements

We acknowledge the support received from Department Agronomy, and Technical staff of the Department Agronomy, AAU, Jorhat, Assam for conducting the field experiment and analysis of samples in the laboratory.

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