Synergistic effects of mulching and integrated nutrient management practices on maize *(Zea mays)*

ABSTRACT

A field experiment on **"Soil moisture conservation and integrated nutrient management practices in *rabi* maize"** was conducted at the Instructional-cum- Research Farm of AAU, Jorhat during the *rabi* season of 2020-21 and 2021-22. The soil of the experimental site was sandy loam in texture with acidic in reaction (pH 5.12 and 5.16), medium in organic carbon (0.65% and 0.69%), medium in available nitrogen (315.50 and 326.25 kg ha^{-1}), high in available phosphorus (37.89 and 39.89 kg ha^{-1}) and medium in available potassium (201.45 and 207.89 kg ha^{-1}). The field experiment was laid out in split plot design with 3 replications. The treatment consisted of three mulching treatments *viz*., M_0; No mulch, M_1:Paddy straw mulch @6t/ha and M_2: Biodegradable plastic film of 20µ in the main plots, and INM practices *viz.*, I_1: 100% recommended dose of fertilizers (RDF), I_2 :100% RDF + Water spray, I_3: 100% PK + 75% RDN + 25% Vermicompost (VC), I_4:100% PK + 75% RDN + 25% Enriched compost(EC) , I_5:100% PK + 75% RDN + 25% VC + 4% Vermiwash, I_6: 100% PK + 75% RDN + 25%EC + 4% Vermiwash, I_7:100% PK + 75% RDN + 25% VC + 4% Humic acid, I_8:100% PK + 75% RDN + 25% EC + 4% Humic acid. Maize variety DKC 9081 was selected for research. Experimental findings revealed that the different soil moisture conservation practices significantly affected the growth parameters like plant height, dry matter accumulation and yield attributes of *rabi* maize. The maximum values of growth parameters were recorded in the treatment involving application of biodegradable plastic mulch. Similar effects were obtained in yield and yield attributing characters *viz*., weight of cob with and without husk, number of rowsper cob, grain per row, grain per cob, 1000 grain weight, grain yield pooled over two years (79.06 q/ha). Among the INM practices the treatment with 100% PK+75% RDN+25% Enriched compost +4% Humic acid (I_8) resulted in significantly higher growth parameters like plant height, leaf area, leaf area index and dry matter accumulation of *rabi* maize. Similarly, yield and yield attributing characters *viz*., weight of cob with and without husk, length of cob, number of rows per cob, grain per row, grain per cob, 1000 grain weight and grain yield (77.56 q/ha) were also higher under this treatment.

Keywords: Vermiwash, Humic acid, Integrated nutrient management

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Introduction

India is a nation with a remarkable diversity of species, including flora, wildlife, andother living things. India's population relies on agriculture for over 70% of their income, which accounts for about 18% of their GDP. The most significant cereal crop in the world, maize is a major staple food for one-third of the world's population. Over 170 nations are currently producing jointly 1147.7 million MT of maize on 193.7 million hectares of land, with an average productivity of 5.75 t ha^{-1}. Maize during *rabi* takes up about 16.93 lakh hectares. The largest states that grow maize are Bihar (5.27 million hectares), Maharashtra (2.27 million hectares), West Bengal (1.52 million hectares), and Assam (31,000 hectares),which produces 91,000 tonnes of the grain each year at a productivity of 2911kg ha^{-1} (FAOSTAT, 2020). Maize is regarded as the third most important cereal crop after wheat and rice (Murdia *et al.*, 2016). Low yield in maize is caused by a variety of biotic and abiotic factors, including nutrient inadequacy, moisture stress, insect pest attack, unpredictable rainfall behavior and other environmental variables. There is nutrient deficit due to abiotic factors including high nutrient fixation in acidic soil and water scarcity during *rabi* season. To avoid these, suitable measures for soil moisture conservation and integrated nutrient management practices were followed. Mulch is defined as any material placed on soil surface to retain moisture, which reduces evaporation losses by acting as a barrier to the movement of soil moisture. Paddy straw mulch conserves the moisture thus, improving the water holding capacity of soil and increase in water use efficiency by 14% [Tolk,1999]. The use of biodegradable film in place of conventional polyethylene might be the ~~best~~ ecofriendly way to improve the ~~yield at the moment~~maize yield~~,~~ [Moreno,2008]. ~~On the other hand,~~Another major constraint associated with ~~Heavy~~ heavy use of chemical ~~fertilizers~~ farming ~~alone~~ [Obi,1995] is ~~causing~~ soil deterioration ~~[~~(Tolk 1999~~][~~; Turner 1986)~~]~~. Thus, ~~Integrating~~ integrating organic fertilizers such as vermicompost, enriched compost, humic acid and vermiwash with chemical fertilizers (RDF) ~~was~~ is ~~helpful in~~ increasingly becoming popular for reducing the harmful effects on ~~-~~soil, plant and human health without reducing yield [Kahlon,2013]. Vermicompost has a wide range of microbial and enzyme activity, fine particle structure, good moisture-holding capacity, and includes nutrients like N, P, K, Ca, and Mg in forms, that plants can easily absorb (Lavelle,1992)~~]~~. Vermiwash is a liquid waste extract that is gathered after water has passed through the various layers of an earthworm culture unit. A literature review proved ~~I~~its successful ~~is used~~ implication as foliar spray in improving ~~yield of~~ crop yields [Raviv,1998]. The exogenously applied humic acid (leonardite) can improve plant growth and yield by supplying macro and micro~~-~~nutrients.

A simple, ~~and~~ very low-cost effective and ecofriendly technique ~~o~~for in~~-~~situ soil moisture conservation in rabi maize (*Zea mays* L.) ~~was~~ is mulching with locally available paddy straw and biodegradable film mulches ~~and~~. The nutrient requirement by crop can further be fulfilled by supplementing the organic amendments with the chemical fertilizers through the system known as integrating nutrient management ~~practices~~. ~~Therefore~~Utilizing this, the present investigation aim~~eds~~ to study the effect of soil

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moisture conservation and integrated nutrient management practices on the growth and yield of rabi maize in Assam. The objectives of the research were 1. To evaluate the effect of soil moisture conservation practices on the growth and yield of rabi maize. 2. To find out the effect of integrated nutrient management practices on growth and yield of *rabi* maize

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Materials and Methods

The field experiment was laid out in split- plot design with three replications. The treatment consisted of three mulching treatments *viz*., M_0; No mulch, M_1:Paddy straw mulch @6t/ha and M_2: Biodegradable plastic film of 20µ in the main plots, andINM practices *viz.,* I_1: 100% recommended dose of fertilizers (RDF), I_2 :100% RDF + Water spray, I_3: 100% PK + 75% RDN + 25% Vermicompost (VC), I_4:100% PK + 75% RDN + 25% Enriched compost(EC) , I_5:100% PK + 75% RDN + 25% VC + 4% Vermiwash, I_6: 100% PK + 75% RDN + 25%EC + 4% Vermiwash, I_7:100% PK + 75% RDN + 25% VC + 4% Humic acid, I_8:100% PK + 75% RDN + 25% EC + 4% Humic acid.

Location of the experimental site

The geographical location of the Instructional cum Research Farm of Assam Agricultural University, Jorhat is situated at 26°45'N latitude, 94°12'E longitude and at an altitude of 87m above mean sea level (MSL). A field with homogeneous soil fertility, gooddrainage, and uniform texture was used for the experiment.

Weather and climatic conditions: Jorhat, included in the upper Brahmaputra valley agro-climatic zone of Assam, hasa subtropical humid climate with warm summers and cool winters. It receives 2500mm ofannual rain on average. June marks the beginning of the monsoon, which lasts through September. In second half of March, pre-monsoon showers are also experienced in the region. Rainfall intensity is highest from June to July and peaks in August. It then progressively declines, with December and January seeing the least amount of precipitation. Along with rain, temperature also rises gradually

Land preparation

The experimental field was thoroughly prepared for sowing using a tractor-drawn disc board plough, and in last week of November 2020, two harrowings were completed, followed by laddering. The plots were cleared of any trash, plant matter that hadn't decomposed. The field was set up according to the experimental design after being properly prepared for use. Seeds of hybrid maize variety, DKC-9081 were sown on 1st December, 2020 and26th November, 2021. Sowing was done manually by dibbling method at a spacing 60 cm x25 cm by using a seed rate of 22.5 kg ha$^{-1.}$ Two levels of mulch treatment comprising paddy straw and biodegradable plastic film were compared with no mulch control treatment for soil moisture conservation and weed suppression in *rabi* maize. Before sowing Paddy straw mulch (M_1) was applied @ 6t ha^{-1} and biodegradable plastic film mulch (M_2) of 20 micron (µ) thickness wasplaced over the plots-. Required amount of nitrogen, phosphorus and potassium in the experimental field was supplied through urea, SSP and MOP, respectively, and through VC and EC as per treatments.

Biometric observations

Measurements of various growth and yield attributing characters were recorded prior to harvesting of the crop to assess the treatment effects. Five plants were chosen at random from the net plot area and tagged for the purpose of recording periodical observations that did not involve destructive sampling. The destructive samples used for measuring the accumulation of dry matter, five plants from the second row from the borderrow in each plot were cut at ground level at each sampling date without disturbing the net plot area and taken to the laboratory with proper tag. The grain yield was collected from each plot bulked, and one thousand grains were selected at random and dried in the sun to bring the moisture content down to roughly 14%. The weight of 1000 grains was then measured according to treatment and stated in grams

Statistical analysis

Data were statistically analyzed by following the method of analysis of variance as suggested by Panse and Sukhatme (1978). Critical difference was worked out at 5 per cent level of probability, wherever the treatmental differences were found significant.Treatment differences that were non-significant were denoted as NS.

Results

Plant height and dry matter: The mean plant height and dry matter accumulation (Table 1) of rabi maize during both the years was found to increase progressively over time and attained the highest value when it was harvested at physiological maturity stage (120 DAS). M_2 exhibited the highest plant height (202.58 cm), followed by M_1 (184.60 cm) and M_0 (179.70cm). Plant height varied among the INM treatments, with I_8 (100% PK + 75% RDN + 25% EC + 4% Humic acid) consistently showing the highest values across all stages, peaking at 198.69 cm at 120 DAS. I_6 (100% PK + 75% RDN + 25% EC + 4% Vermiwash) also performed well, particularly notable at 120 DAS with a plant height of 195.73 cm. Similar pattern was followed with dry matter accumulation (Table 1), M_2 exhibited the highest dry matter accumulation across all stages, with 11.18 g/plant at 30 DAS, 49.31 g/plant at 60 DAS, 91.14 g/plant at 90 DAS, and 124.33 g/plant at 120 DAS. M_1 showed moderate results, whereas M_0 had the lowest dry matter accumulation, indicating the beneficial impact of mulching on biomass production. Among the INM practices, I8 demonstrated the highest dry matter accumulation, reaching 11.30 g/plant at 30 DAS and increasing significantly to 110.28 g/plant at 120 DAS. I_6 and I_7 also showed high dry matter accumulation after I_8, indicating the positive effect of combining organic amendments with chemical fertilizers. I_1 consistently recorded the lowest values, highlighting the limitation of using only the recommended dose of fertilizers without additional organic inputs.

Grain yield, weight of grains/cob, Shelling %, Test weight and grain yield

The Table 2 shows the impact of different soil moisture conservation practices and INM practices on grain yield and yield parameters across two growing seasons (2020-21 and 2021-22. During both the years, the treatments revealed notable differences in the number of grains per cob, weight of grains per cob, shelling percentage, test weight, and grain yield. The M_2 treatment exhibited the highest number of grains per cob at 408.83, significantly outperforming M_1 (294.69) and M_0 (273.44) during 2020-21 and M_2 (416.87), M_1 (294.83) and M_0 (277.21) during 2021-22. M_2 also showed the highest weight of grains per cob at 116.48 g, compared to 96.6 g in M_1 and 78.71 g in M_0. The weight of grains per cob during 2021-22 in M_2 increased to 132.24 g, significantly higher than 102.84 g in M_1 and 85.65 g in M_0, showing continued improvement. The shelling percentage was slightly higher in M_2 at 77.5% compared to 76.87% in M_1 and 76.42% in M_0, indicating a marginal improvement in grain filling with advanced practices. Similarly, M_2 exhibited the highest shelling percentage at 80.98%, compared to 78.5% in M_1 and 77.08% in M_0 indicating better grain filling in advanced treatments in second season. However, our research found no significant differences in shelling percentage between the different mulching and integrated nutrient management (INM) treatments across both the years.

The test weight followed a similar trend, with M_2 showing the highest value at 282.85 g, M_1 at 276.82 g, and M_0 at 271.44 g in 2020-21 and M2 at 282.05 g, with M1 and M0 at 277.31 g and 272.14 g, respectively in 2021-22, showing stable test weight. The maximum test weight was observed in the M_2 treatment, which employed mulching. The grain yield was highest in M2 at 76.25 kg/ha, compared to 66.88 kg/ha in M1 and 64.58 kg/ha in M0, highlighting the significant yield advantage of advanced soil moisture conservation practices. Grain yield in M2 further increased to 81.88 kg/ha, compared to 73.78 kg/ha in M1 and 68 kg/ha in M0, underscoring the sustained yield benefits of advanced soil moisture practices. The sub-plot treatments (I1 to I8) also showed significant variations. The number of grains per cob ranged from 302.41 in I1 to 350.71 in I8, with I8 showing the highest values, reflecting the effectiveness of more intensive conservation practices. The number of grains per cob ranged from 307.61 in I1 to 351.05 in I8, with I8 maintaining the highest values, confirming the effectiveness of intensive conservation practices. The weight of grains per cob varied from 92.6 g in I1 to 102.42 g in I8, again indicating superior performance with more intensive practices. Weight of grains per cob increased across all treatments, with I8 showing the highest at 116.31 g, up from 102.42 g the previous year. Shelling percentage ranged from 74.88% in I1 to 80.75% in I8, suggesting better grain filling. Shelling percentage was highest in I8 at 80.22%, reflecting improved grain filling in intensive treatments. Test weight varied from 275.7 g in I1 to 279.97 g in I8, with higher values indicating better grain quality. Test weight remained high, with values ranging from 275.64 g in I1 to 278.87 g in I8, indicating consistent grain quality.Grain yield ranged from 64.3 kg/ha in I1 to 75.67 kg/ha in I8, with I8 showing the highest yield, highlighting the benefits of intensive soil moisture conservation. Grain yield increased in all sub-plot treatments, is showing the highest at 79.44 kg/ha, high lighting the benefits of intensive soil moisture conservation. Among INM practices, maximum values obtained with I8:100% PK+75% RDN+25% EC+ 4% Humic acid which was at par with I6 which formed by the combination of EC + vermiwash. Significant difference in grain yield /hectare (75.67q/ha in 2020-21, 79.44q/ha in 2021-22) was noticed among INM treatments, The percent (%) yield increase by INM treatments was 17.68 % and 12.4% during both the years in combination such as enriched compost with humic acid and with enriched compost and vermiwash showed 73.19 q/ha (12.13%) and 77.14 q/ha (8.15%) better results. Whereas, the combination of vermicompost and humic acid increased yield to 14.99% and 9.23 % during both the years.

Table 1: Effect of mulches and Integrated Nutrient Management practices on plant height and dry matter accumulation of *rabi* maize.

Treatments	Plant height				Dry matter accumulations			
	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS
Main plot treatments								
M_0	21.79	56.82	163.64	179.77	9.41	34.63	74.80	93.73
M_1	25.62	64.37	174.80	184.60	11.02	42.03	83.02	104.17
M_2	24.78	74.33	193.26	202.58	11.18	49.31	91.14	124.33
SEm±	0.690	0.913	1.498	3.146	0.099	0.929	1.070	1.732
CD (P=0.05)	2.711	3.584	5.881	12.352	0.387	3.647	4.199	6.798
Sub-plot treatments								
I_1	22.68	58.73	168.03	179.84	9.97	38.91	79.26	103.97
I_2	22.80	58.67	169.72	181.81	9.88	39.22	80.11	105.31
I_3	23.87	65.27	172.58	186.39	10.44	40.71	81.71	106.32
I_4	24.68	65.95	175.99	187.73	10.34	41.76	82.96	107.36
I_5	24.47	66.55	178.48	189.04	10.47	42.31	83.68	108.17
I_6	25.90	68.65	186.06	195.73	11.12	43.98	84.93	108.44
I_7	23.72	67.28	180.99	192.65	10.79	42.95	84.57	109.44
I_8	24.40	70.30	186.03	198.69	11.30	46.11	86.67	110.28
SEm±	0.935	1.323	1.856	3.091	0.382	1.397	1.237	2.055
CD (P=0.05)	*	3.776	5.296	8.822	NS	3.988	3.530	*

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Table 2: Effect of soil moisture conservation and Integrated Nutrient Management practices on yield and yield attributes of *rabi* maize

Treatments	Grains/cob		Weight of grains/cob		Shelling %		Test weight		Grain yield	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
Main plot treatments										
M0	273.44	277.21	78.71	85.65	76.42	77.08	271.44	272.14	64.58	68
M_1	294.69	294.83	96.6	102.84	76.87	78.5	276.82	277.31	66.88	73.78
M_2	408.83	416.87	116.48	132.24	77.5	80.98	282.85	282.05	76.25	81.88
SEm±	4.826	6.02	2.065	1.971	0.958	1.581	1.648	1.372	1.413	0.993
CD (P=0.05)	18.947	23.635	8.109	7.739	NS	NS	6.47	5.385	5.547	3.899
Sub-plot treatments										
I_1	302.41	307.61	92.6	98.26	74.88	78	275.7	275.64	64.3	70.62
I_2	309.15	308.88	93.34	100.5	75.2	79.27	274.88	275.75	65.24	71.36
I_3	317.96	322.86	94.84	103.82	75.58	78.16	276.68	277.07	66.07	72
I_4	321.05	326.57	94.91	105.03	75.29	76	276.4	277.18	67.1	73.17
I_5	329.26	334.26	99.1	108.51	77.09	80.15	276.9	277.15	69.48	76.3
I_6	338.83	344.52	100.43	111.75	77.84	79.45	276.82	277.37	73.94	77.14
I_7	335.84	341.34	100.45	111.11	78.81	79.58	278.93	278.3	72.1	76.38
I_8	350.71	351.05	102.42	116.31	80.75	80.22	279.97	278.87	75.67	79.44
SEm±	6.918	7.719	2.157	3.013	1.498	1.821	1.475	1.161	1.391	1.502
CD (P=0.05)	19.746	22.031	6.157	8.601	*	*	*	*	3.97	4.286

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Discussion:

The mean plant height and dry matter accumulation of rabi maize during both the years was found to increase progressively over time and attained the highest value when it was harvested at physiological maturity stage (120 DAS). M_2 exhibited the highest plant height. The increase in plant height, dry matter accumulation could be explained by [Cihangir (2020)]. Mulching provides enhanced crop microclimate through provision of improved rainwater harvesting and utilization, which helps in maintaining higher leaf turgor, elongation rate and overall photosynthesis for improved C fixation in terms of dry matter production and plant height (Singh et al 2022). Findings are in accordance with (Misra et.al (1996)) who also found reported that soil mulching increased the amount of moisture that could be stored in the soil profile and considerably improved plant water use efficiency and plant overall growth and yield during both the years, which contribute in increasing grains per cob. This suggests that M_2 not only increases the plant morphological characters but also enhance the yield parameters such as number of grains and also increases grain weight. The improved plant photosynthesizing system caused by mulching further elevate the assimilate partitioning from source leaves to the developing grains for attaining higher grain weights (Singh et al 2024). This finding aligns with the study Chakraborty (2008) and Singh et al (2022), which also reported enhanced grain weight under mulched conditions due to improved soil moisture retention and efficient rainwater harvesting and use. This suggests that these specific agronomic practices did not influence the ease of shelling %. These findings are consistent with previous research indicating that shelling percentage is largely influenced by genetic factors and the physical characteristics of the cob and kernels rather than agronomic practices Li, J (2003). This increase in test weight can be attributed to the enhanced soil moisture availability provided by mulching during critical growth periods. Mulching helps in conserving soil moisture by reducing evaporation, thereby ensuring that plants have a consistent water supply, which is crucial for achieving optimal grain filling and test weight. This observation is consistent with findings Chakraborty (2008) who reported similar benefits of mulching in improving grain weight due to better soil moisture conservation.

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The impact of humic acid on certain plant processes like respiration and photosynthesis, as well as the improvement in photosynthesis efficiency and the subsequent provision of food stocks that then move to the seeds that are formed and increase the fullness and then increase weight. The vermiwash showed better results after humic acid. This is explained by slower nutrient release for absorption with extra nutrients like gibberellin, cytokinnin, and auxins, as well as by the use of organic inputs in conjunction with vermiwash [Raviv(1998)].Conversely, our study did not find any significant effects of integrated nutrient management (INM) practices on test weight. While INM is effective in improving soil fertility and overall crop yields through a balanced supply of nutrients, it appears that its influence on test weight is minimal. This suggests that test weight is more closely related to soil moisture availability and other environmental factors rather than nutrient management alone.

Conclusion

Based on two years of field experimentation, it may be concluded that the different mulch materials were found to be advantageous in ~~conserving~~ improving crop microclimate through enhanced soil moisture, which ~~and~~ increaseding the crop growth, physiological and photosynthetic performance for ~~and~~ higher grain growth and yield of maize in *rabi* season. ~~In case~~ Across different ~~of~~ integrated nutrient management practices, the application of 100% PK and 75% RDN along with enriched compost and foliar spray of 4% humic acid were observed ~~as found~~ pivotal in ~~to increas~~attaining the peak ~~e~~ production. ~~yield~~

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