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Integrated nutrient management in maize (*Zea mays*) under different microclimatic regimes

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ABSTRACT

A field experiment entitled was conducted during summer season of 2020 and 2021 at the research farm of Assam Agricultural University, Jorhat, Assam with an objective to study the effect of microclimatic regime and integrated nutrient management in maize. The experiment was laid out in a split-plot design with 3 replications. Results revealed that among the different microclimatic regimes, crop sown on 15th March resulted in significantly higher values in almost all the growth characters, yield attributing characters, and yield as compared to other dates of sowing. Among the different integrated nutrient management practices, application of 75% of RDN through urea + 25% RDN through enriched compost (N_4) recorded significantly higher value in respect of growth parameters, yield attributing characters and cob yield as compared to RDF, but remain at par with 75% of RDN through urea + 25% RDN through vermicompost (N_2).

Keywords: Integrated nutrient management, Maize, Microclimatic regimes, Yield

Maize (*Zea mays* L.) is one of the most versatile emerging cereal crops of Assam. It can be grown under varied agro-climatic condition throughout the year due to its photo-thermo-insensitive character. The summer maize is gaining popularity among farmers of Assam because of short-growth period and high production potential of hybrid maize in irrigated as well as rainfed conditions. In recent years, specialized and commercially intensive livestock and poultry farmers are increasing in Assam which increased the demand of maize in the market. Hence, farmers are developing more interest in cultivating maize during summer season because of increasing market price and assured industrial use.

Nutrient management strategies play a vital role in sustainable production of crop. Farmers are using huge amount of chemical fertilizers. This excessive use of chemical fertilizer has been associated with decline in soil physical and chemical properties and crop yield (Kumar *et al*. 2016). Efficacy of organic sources to fulfill the nutrient demand of crop is not as assured as mineral fertilizers, but the joint use of inorganic fertilizers along with various organic sources is capable of higher crop productivity along with improving the soil quality on long-term basis. Hence, instead of applying recommended dose of nitrogen through chemical fertilizers, a strategy of integrated use of recommended dose of nitrogen through inorganic sources in combination with different organic sources, which is available locally should be developed to meet the nitrogen requirement of crops without deteriorating the soil and other natural resources. It is necessary to identify the best available organic resources which can be used in combination with appropriate proportion of inorganic fertilizers to achieve maximum yield potential of crops.

Changing environmental conditions associated with different sowing dates had a significant effect on growth and development of maize plant. Adjustment of sowing date also helps to escape the unfavorable condition which adversely affects the maize yield in Assam. Keeping these points in view, the present investigation under rainfed condition has been proposed to adjust the sowing time to accommodate the crop in most favorable microclimatic conditions to improve the nitrogen use efficiency through integrated nutrient management.

MATERIALS AND METHODS

An experiment was conducted at the research farm of Assam Agricultural University, Jorhat, Assam during the summer season of 2020 and 2021. In the year 2020, during the crop growth period the maximum and minimum temperature ranged from 25.3–33.5°C and 12.4–25.4°C respectively. The weekly average relative humidity during the morning hours ranged from 87–97% while mean evening relative humidity ranged from 56–87%. Based on 30 years of rainfall data from 1981–2010, the average

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normal rainfall of Jorhat during the crop growing period (February–June) was workout as 821.8 mm. But during the time of experimentation the total precipitation was less than the average i.e. 780.8 mm, out of which maximum 146.5 mm was received in 25th SMW (Standard Meteorological Week) and minimum 0.4 mm of rainfall recorded in 8th SMW and 11th SMW while there is a complete absence of rainfall in 10th and 12th SMW. The bright sunshine hours during the crop growing period ranged from 0.5–7.25 h/day. Number of rainy days during the growth period was 43 days.

In the year 2021, the maximum and minimum temperature during the crop growth was ranged from 26°C to 34.1°C and 11.7°C to 25°C respectively. The crop received 538.3 mm rainfall during the growing period which was less than the normal average rainfall. The distribution of rainfall was uneven and maximum rainfall 73.5 mm was received in 25th SMW and minimum rainfall 0.8 mm of rainfall recorded in 14th SMW. The complete absence of rainfall was recorded in 7th SMW, 8th SMW, 12th SMW, 15th SMW and 17th SMW. The crop received bright sunshine hours ranging from 1.0–9.1 h/day during the growing period. The total numbers of rainy days during the period were 41 days.

The experiment was laid out in a split-plot design with 3 replications, viz. main-plot treatments (Microclimatic regimes) M_1, 15th February; M_2, 1st March; M_3, 15th March and sub-plot treatments (Integrated nutrient management) N_1, 100% RDF (60-40-40 kg/ha N-P_2O_5, K_2O); N_2, 75% of RDN through urea + 25% RDN through vermicompost; N_3, 75% of RDN through urea + 25% RDN through FYM; N_4, 75% of RDN through urea + 25% RDN through enriched compost.

The soil of the experimental site was sandy loam, acidic (*p*H 5.12 and 5.18), medium in organic carbon (0.65% and 0.71%), available P_2O_5 (22.68 kg/ha and 22.87 kg/ha) and available K_2O (144.50 kg/ha and 147.60 kg/ha) while low in available N (229.47 kg/ha and 221.32 kg/ha) during 2020 and 2021 respectively. The maize variety PAC 751 was sown as per treatment. Manures and fertilizers were applied as per treatment.

Different nutrient content of the organic manures

Nutrients (%)	FYM	Vermicompost	Enriched compost
N	0.5	1.55	2.1
P	0.2	0.80	1.2
K	0.5	1.36	2.3

RESULTS AND DISCUSSION

Growth characters: Data (Table 1) revealed that among the different dates of sowing, the plant height of maize was found to be increased with advancement of sowing date during both the years of study. The highest values of plant height at 60 Days after sowing (DAS) (105.86 cm and 107.44 cm) and 90 DAS (158.38 cm and 160.09 cm) in 2020 and 2021 were recorded in crop sown on 15th March followed by 1st March. The effect of integrated nutrient management on plant height of maize was found to be significant in all the growth stages except for 30 DAS in 2020 and 2021. However, the plant height at 60 DAS and 90 DAS were found to be highest at 75% of RDN through urea + 25% RDN through enriched compost which was at par with 75% of RDN through urea + 25% RDN through vermicompost and the lowest value was recorded under RDF in both the years.

The data (Table 1) revealed that at 30, 60 and 90

Table 1 Effect of microclimate and integrated nutrient management on plant height and dry matter accumulation of maize

Treatment	Plant height (cm)						Dry matter accumulation (g/plant)					
	30 DAS		60 DAS		90 DAS		30 DAS		60 DAS		90 DAS	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Microclimatic regimes												
M_1	31.06	31.03	95.09	96.09	145.95	148.81	7.27	7.42	63.43	66.25	136.38	137.50
M_2	32.72	34.38	102.32	104.86	155.13	157.99	8.78	9.13	69.58	71.42	143.67	144.75
M_3	32.90	35.58	105.86	107.44	158.88	160.09	8.86	9.19	71.83	73.50	149.17	150.42
SEm (±)	0.70	1.08	1.70	1.19	2.26	1.78	0.38	0.23	1.27	0.49	0.94	0.65
CD (P=0.05)	NS	NS	5.89	4.12	7.83	6.15	1.33	0.79	4.39	1.70	3.24	2.26
Integrated nutrient management												
N_1	30.41	32.44	96.26	97.38	146.73	150.60	7.48	7.66	65.13	68.17	138.67	140.44
N_2	32.44	33.77	102.10	103.77	155.84	158.38	8.59	9.28	68.78	71.06	145.39	145.89
N_3	32.23	33.48	100.58	102.44	150.96	151.80	8.00	8.17	67.50	69.22	141.72	142.11
N_4	33.82	34.96	105.41	107.61	159.67	161.74	9.15	9.68	71.72	73.11	147.50	148.44
SEm (±)	0.88	0.75	1.46	1.53	1.38	1.45	0.24	0.16	1.16	0.88	1.02	0.82
CD (P=0.05)	NS	NS	4.27	4.46	4.03	4.24	0.70	0.45	3.40	2.57	2.98	2.38

RDN, Recommended doses of nitrogen; FYM, Farm Yard Manure; RDF, Recommended doses of fertilizer; NS, Non-significant. Treatment details are given in Materials and Methods.

Table 2 Effect of microclimate and integrated nutrient management on LAI of maize

Treatment	Leaf Area Index					
	30 DAS		45 DAS		60 DAS	
	2020	2021	2020	2021	2020	2021
Microclimatic regimes						
M_1	1.31	1.57	3.43	3.60	4.13	4.36
M_2	1.32	1.68	3.77	3.90	4.48	4.85
M_3	1.50	1.75	3.80	4.08	4.67	5.19
SEm (±)	0.05	0.04	0.06	0.07	0.10	0.07
CD (P=0.05)	NS	NS	0.20	0.23	0.36	0.23
Integrated nutrient management						
N_1	1.27	1.57	3.39	3.53	4.06	4.32
N_2	1.40	1.71	3.76	3.99	4.58	4.98
N_3	1.34	1.63	3.57	3.79	4.40	4.76
N_4	1.49	1.74	3.94	4.12	4.67	5.14
SEm (±)	0.08	0.05	0.07	0.10	0.12	0.11
CD (P=0.05)	NS	NS	0.21	0.29	0.35	0.32

RDN, Recommended doses of nitrogen; FYM, Farm Yard Manure; RDF, Recommended doses of fertilizer; NS, Non-significant. Treatment details are given in Materials and Methods.

DAS, the dry matter production was highest in crop sown on 15th March which was at par with 1st March sowing at 30 DAS during both the years but at 60 DAS, crop sown on 15th March remain at par with crop sown on 1st March only in 2020. Among the different treatments, dry matter accumulation was highest in 75% of RDN through urea + 25% RDN through enriched compost which was at par with 75% of RDN as urea + 25% RDN as vermicompost and significantly higher than other treatments at 30, 60 and 90 DAS during both the years. Data (Table 2) revealed that the highest value of leaf area index at 45 DAS (3.80 and 4.08) and 60 DAS (4.68 and 5.19) were observed under 15th March which was at par with crop sown on 1st March in 2020 and 2021, respectively.

The data (Table 1 and 2) revealed that the crop sown on 15th March recorded the higher values of various growth parameters studied over the other two dates of sowing. This may be due to late sown crop may enjoy favourable climatic conditions in terms of temperature, rainfall, soil moisture content and the other climatic parameter during various crop growth stages, which reflected into early germination and initial vigorous growth of plant compared to early sowing. Similar result was reported by Panda and Dutta (2019). Among the different integrated nutrient management treatments, the plant height, LAI, dry matter accumulation, were found to be highest in 75% of RDN through urea + 25% RDN through enriched compost. In case of full dose of chemical fertilizer, the nutrient losses especially through N leaching, N volatilization etc affected the nutrient availability to the plant. Beneficial effect in INM is due to the stabilization of applied nutrient with organic source and subsequent release to fulfil the requirement of growing crop. These results are in line with the findings of Kumar *et al.* (2016), Borah *et al.* (2018), Neelam and Dutta (2018) and Bezboruah and Dutta (2021).

Yield attributes: Data (Table 3) revealed that the highest number of kernel rows per cob was observed in 15th March sown crop which was significantly higher than other two dates of sowing. Maximum weight of cob without husk was found in 15th March which was at par with 1st March during both the years of studies. The results are in close proximity with findings of Hassaan (2018), Panda and Dutta (2019) and Ali *et al.* (2020).

Among the different integrated nutrient management treatments, maximum number of kernel rows per cob, maximum number of kernels per cob and maximum weight of cob without husk were observed with treatment 75% of RDN through urea + 25% RDN through enriched compost in both the years. All the parameters related to yield attributing characters under INM practices were found to be better over RDF. Use of fertilizers along with organic sources increased nutrients availability and provided nutrition in plant ready form immediately. This findings confirms the results reported by Borah *et al.* (2018).

Yield (q/ha): The data (Table 3) revealed that different microclimatic regimes significantly influenced the cob yield of maize. Maximum cob yield (56.11 q/ha and 56.86 q/ha) were observed in crop sown on 15th March in 2020 and 2021 which were at par with crop sown on 1st March in both the years of studies. The lowest cob yield (51.69 q/ha and 52.53 q/ha) were recorded under 15th February sowing in 2020 and 2021, respectively. The kernel yields also followed the same trend. There was an increasing trend in stover yield of maize with delay in sowing date from 15th February to 15th March. The maximum stover yields (79.83 q/ha and 80.42 q/ha) were recorded under 15th March

Table 3 Impact of microclimate and integrated nutrient management on yield attributes and yield of maize

Treatment	No. of kernel rows per cob		No. of kernels per cob		Wt. of cob without husk (g/cob)		Cob yield (q/ha)		Kernel yield (q/ha)		Stover yield (q/ha)	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Microclimatic regimes												
M_1	11.84	12.75	300.17	326.94	156.83	168.92	51.69	52.53	36.08	37.33	75.58	77.70
M_2	12.82	13.31	341.25	359.45	176.83	182.58	54.95	55.62	39.37	40.28	77.92	79.42
M_3	13.71	14.21	395.58	393.19	188.67	193.67	56.11	56.86	40.72	41.30	79.83	80.42
SEm (±)	0.31	0.11	9.11	4.56	4.18	4.27	0.66	0.46	0.90	0.66	0.41	0.42
CD (P=0.05)	1.08	0.38	31.54	15.77	14.46	14.78	2.29	1.58	3.10	2.30	1.42	1.44
Integrated nutrient management												
N_1	11.73	12.22	301.78	307.89	160.22	167.22	50.67	51.45	35.11	36.22	74.89	76.94
N_2	13.33	13.51	360.89	364.80	180.33	187.89	56.27	56.83	40.33	41.22	78.89	79.89
N_3	12.06	13.16	323.11	349.45	172.44	181.00	52.56	53.00	38.11	38.55	77.33	79.11
N_4	14.03	14.79	396.89	417.31	183.44	190.78	57.51	58.73	41.33	42.55	80.00	80.78
SEm (±)	0.59	0.40	18.53	14.30	3.72	2.04	0.89	0.74	1.04	0.74	0.71	0.55
CD (P=0.05)	1.71	1.17	54.09	41.74	10.87	5.96	2.59	2.17	3.02	2.17	2.07	1.59

RDN, Recommended doses of nitrogen; FYM, Farm Yard Manure; RDF, Recommended doses of fertilizer; NS, Non-significant. Treatment details are given in Materials and Methods.

sowing in 2020 and 2021, respectively. This might be due to the maximum absorption and utilization of solar energy resulted in highest value of growth and yield attributes due to favourable weather condition which finally increased the kernel and stover yield. These findings are in agreement with Panda and Dutta (2019). The highest cob yields (57.51 q/ha and 58.73 q/ha in 2020 and 2021 respectively) recorded under the treatment 75% of RDN through urea + 25% RDN through enriched compost in 2020 and 2021 which were at par with 75% of RDN through urea + 25% RDN through vermicompost in both the years. The lowest value was observed in treatment RDF.

The maximum kernel yields (41.33 q/ha and 42.55 q/ha in 2020 and 2021 respectively) were recorded in the treatment 75% of RDN through urea + 25% RDN through enriched compost and the minimum kernel yields (35.11 q/ha and 36.22 q/ha in 2020 and 2021 respectively) were recorded under RDF (Table 3). Kernel yield obtained from the treatment 75% of RDN through urea + 25% RDN through enriched compost was found at par with kernel yield obtained in the treatment 75% of RDN through urea + 25% RDN through vermicompost. The kernel yield of maize was increased by 12.8% in 2020 and 10.63% in 2021 under the treatment 75% of RDN through urea + 25% RDN through enriched compost over the application of recommended doses of fertilizer. Stover yield was significantly affected by integrated nutrient management practices. The highest stover yields (80.00 q/ha in 2020 and 80.78 q/ha in 2021) were recorded under the treatment 75% of RDN through urea+ 25% RDN through enriched compost which was at par with 75% of RDN through urea + 25% RDN through vermicompost. These treatments recorded significantly higher stover yield than RDF. Stover yield increased in treatment N_4 was 5.90% higher than RDF. Mugwe *et al.* (2009) reported that application of organic combination with inorganic fertilizer produced significantly higher maize yields than with only inorganic fertilizer. Similar, effect was also reported earlier by Dilshad *et al*. (2010).

Higher cob and stover yields found in INM practices with 75% of RDN through urea + 25% RDN through enriched compost treatment was due to increased availability of nutrients, hormones and minerals from enriched compost. During the time of preparation of enriched compost ingredient like rock phosphate, *Azospirillum* and PSB were used for enrichment. *Azospirillum* is a free-living nitrogen fixing bacteria which can promote plant growth. The beneficial effect of *Azospirillum* may derive both from its nitrogen fixation and stimulating effect on root development. On the other hand, PSB can solubilize the fixed soil P and applied phosphate resulting in higher crop yields. Phosphate and potassium solubilizing bacteria may enhance mineral uptake by plants through solubilizing insoluble P and releasing K from silicate in soil. Ultimately all these factors maintained a favourable soil physical, chemical and biological environment resulting better growth and development in yield attributes which reflected in grain and stover yield of crop. Beneficial effect of integrated nutrient management was also reported by Jinjala *et al.* (2016).

On the basis of the results obtained from the investigation, it can be concluded that the performance of maize with respect to yield attributing characters, kernel yield and stover yield were found to increase with every 15 days delay in sowing time from 15th February to 15th March under all the integrated nutrient management practices. Among the different treatment combinations of

microclimatic regime and INM practices, the crop sown on 15th March with 75% RDN through urea + 25% RDN through enriched compost gave satisfactory result in respect of yield and soil health. Since the findings are generated based on two years of experimentation, microclimatic regime 15th March with application of 75% RDN through inorganic + 25% RDN through enriched compost may be suggested under the agro-climatic condition of Assam.

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