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Effect of microclimatic regimes and nitrogen management practices on phenology, yield and agrometeorological indices for *rabi* maize

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Abstract

The field experiment was conducted during *rabi* seasons of 2016-17 and 2017-18 to study the effect of microclimatic regimes and nitrogen management practices on phenology, yield and agrometeorological indices for maize. The experiment was laid out in Factorial Randomized Block Design (FRBD) with three replications and sixteen treatments with four different microclimatic regimes (M_1 – 1 November, M_2 – 15 November, M_3 – 1 December, M_4 – 15 December) and four nitrogen management practices (N_1: 100 % RDF of N as inorganic; N_2: 75% N as inorganic + 0.5 t ha^{-1} vermicompost (V.C.); N_3: 50 % N as inorganic + 1.0 t ha^{-1} V.C.; N_4: 25% N as inorganic + 1.5 t ha^{-1} V.C.). The crop sown on November 1 required significantly higher number of days and accumulated GDD and accumulated HTU to attain various phenophases compared to other date of sowings. Highest number of grains cob^{-1}, 1000-grain weight, grain weight cob^{-1} and yield were recorded in the crop sown on November 1 and decreased with delay in sowing. Application of 50 % N as inorganic along with vermicompost @ 1.0 t ha^{-1} recorded significantly higher number of grains cob^{-1}, 1000-grain weight, grain weight cob^{-1} and grain yield compared to other nitrogen management practices.

Keywords: Agrometeorological indices, microclimatic regime, N management, *rabi* maize

Introduction

Maize is the third most important cereal crop of world and India after wheat and Rice. Maize has been an important cereal crop sowing to its highest production potential and adaptability to wide range of environment hence called as 'Queen of Cereals' (Choudhari and Channappagouda, 2015) [6]. In India, the crop is grown on an area of 9.38 million ha with the grain production of is 28.75 million tonnes, with an average productivity of 3065 kg ha^{-1} (DACNET, 2019) [7]. In Assam, it covers an area of about 28420 ha with a production of 0.87 lakh metric tonnes and productivity of 3067 kg ha^{-1} (Anonymous, 2017) [3]. Among several agronomic practices, date of sowing is an important non-monetary input for realizing higher productivity in maize. The maximum productivity will be achieved by sowing the crop at optimum time which is mainly dependent on the agro-climatic conditions of the region. Sowing before or after the optimal date usually results in substantial yield reduction in maize.

It was observed that the late planting of winter maize after second fortnight of October is suffered with adverse fall in temperature at the early growth stages. The lower temperature below the base temperature (8^{o}C) during the winter sometimes adversely affects the maize yield and late winter planting is considered less monetary return than the early spring planting (Amgain, 2011) [2]. Though maize is a day neutral plant, the flowering and maturity of its varieties are however, dependent on available temperature and sunshine hours and it is location specific (Rao *et al*., 1999) [15]. The growing degree days (GDD) are often used to relate crop growth and yield to meteorological conditions prevailing during crop growing period. Crop sown on different dates and irrigation given at different crop growth stages provides sufficient information to find out the best option with logical understanding (Sharangi and Roychowdhury, 2014) [18].

Nutrient management is important for sustainable crop production. Among the major nutrients, nitrogen management is essential for increasing N use efficiency as well as productive efficiency. From the sustainability point of view, alternatives have to be found out to increase the nitrogen utilization efficiency without hindering the productive capacity of soils. In the face of the continuing global energy crisis and progressively prohibitive cost of fertilizer nitrogen, there is renewed interest towards sustainable low cost alternatives like organic manures. Instead of using higher than recommended dose of nitrogen exclusively through inorganic fertilizer, a strategy of integrated use of recommended dose of nitrogen through inorganic in combination with any amount of organic sources, which is abundantly available locally should be tried to satisfy the higher nitrogen requirement of crops, without impairing soil health. Vermicompost is a good source of almost all essential nutrients. But the concentration of nutrients is less as compared to chemical fertilizers. Enrichment of compost in terms of increasing the nutrient content through microbial enrichment technique with bio-inoculants to composting material had been shown to improve the quality of compost (Borah *et al*., 2014) [4]. Considering the above facts, the present investigation was carried out with the objective to study the effect of different microclimatic regimes and nitrogen management practices on phenology, yield and agrometeorological indices for *rabi* maize in Upper Brahmaputra Valley Zone of Assam.

Materials and Methods

The field experiments were conducted at the farm of KVK of Tinsukia district during *rabi* seasons of 2016-17 and 2017-18 in maize. The soil was sandy clay loam with pH of 5.12 and 5.23, high in organic carbon 0.85% and 0.90%, medium in available N (298.75 kg ha^{-1} and 310.45 kg ha^{-1}) and available P_2O_5 (25.92 kg ha^{-1} and 26.13 kg ha^{-1}) and very low in available K_2O (33.5 kg ha^{-1} and 34.4 kg ha^{-1}) at the start of the experiment during 2016-17 and 2017-18, respectively. The experiment was laid out in factorial RBD with three replications. The treatments consisted of four micro climatic regimes (M_1 - 1 November; M_2 - 15 November; M_3 -1 December; M_4 - 15 December) and N management (N_1: 100 % RDF of N as inorganic; N_2: 75% N as inorganic + 0.5 t ha^{-1} vermicompost (V.C.); N_3: 50 % N as inorganic + 1.0 t ha^{-1} V.C.; N_4: 25% N as inorganic + 1.5 t ha^{-1} V.C.). The microclimatic regimes were developed by sowing the crops in different dates. The crop was fertilized with a uniform dose of 60:40:40 kg ha^{-1} of N, P_2O_5 and K_2O, respectively. Full dose of P_2O_5 and K_2O and 1/3rd dose of N were applied at the time of sowing as per the treatments. Remaining 2/3rd dose of N were applied in two equal splits at knee height and before tasseling stage. Vermicompost were incubated with *Azotobacter* and Phosphorous Solubilizing Bacteria (PSB) for 15 days @ 0.2 % (w/w). Incubated vermicompost were applied at a specified rate as per the treatments. Maize (Vivek maize hybrid 45) seed @ 22.5 kg ha^{-1} was sown manually in lines by maintaining a spacing of 60 cm × 25 cm. Agronomic management practices and plant protection measures were followed as per the recommendation. The occurrence of phenological events like tasseling, silking and maturity in maize were recorded from each plot and average dates of these phases were calculated and used for analysis. Observations on various yield attributes were recorded at harvest following standard procedure. At maturity, the crop was harvested from the net plot area and grain yield was determined. Daily maximum and minimum temperature and sunshine hours during crop growing period were recorded from the agrometeorological observatory. The accumulated growing degree day (GDD) or heat unit was worked out using the following equation (Nuttonson, 1955) [12]:

$$\text{Growing Degree Day (°C day)} = \left\{ \frac{(T_{max} + T_{min})}{2} \right\} - T_{base}$$

$$\text{Accumulated growing degree days (AGDD)} = \sum_{i=1}^{n} \text{GDD}$$

Where, T_{max} is the daily maximum temperature (°C); T_{min} is the daily minimum temperature (°C); T_{base} is the base temperature considered as 10 °C; n is the number of days taken for completion of particular growth phase. The helio-thermal unit for a given day represents the product of GDD and the actual hours of bright sunshine for that day. The sum of HTU for the duration of each phenophase was determined by using the formula given by Monteith (1984) [10] as:

Accumulated HTU (°C day) =∑ (GDD x Actual sunshine hours)

The results of both the years were more or less similar and hence two years data were pooled and analyzed statistically to draw suitable inference as per standard ANOVA technique described by Panse and Sukhatme (1985) [13].

Results and Discussion

Phenophase duration

Data (Table 1) show that microclimatic regimes brought significant variation in number of days taken to attain tasseling, silking and maturity stage. The crop sown on 1 November (M_1) took 78 days to attain tasseling stage whereas 15 December (M_4) sown crop took 70 days to attain that stage. More number of days taken to attain maturity in early sown crop might be due to lower temperature experienced by the crop at latter stages. The late sown crop (15 December) shortened maturity period due to higher ambient temperature during later stages of growth. The results are in close conformity with Verma *et al*. (2012) [19]. Shah *et al*. (2012) [17] also reported that delayed sowing of maize had relatively squeezed the reproductive phase of development which adversely affected grains development and hence resulted in lower grain index which caused loss for the grain yield.

Yield and yield attributes

An assessment of data (Table 2) indicates that higher number of grains cob^{-1}, 1000-grain weight and grain weight cob^{-1} was observed in the crop sown on 1 November (M_1) which was significantly superior over others date of sowing. Higher number of grains cob^{-1} (300.7) on 1 November sown crop might be due to combined effect of accumulation of more photosynthates, cooler temperature with higher relative humidity during tasseling and silking and also to increased fertile ovules further developed more number of grains. However, combined effects of low temperature and longer crop duration during grain development increased number of grains with early sowing. Similar findings were also reported by Ahsan *et al*. (2013) [1]. Higher 1000-grain weight (224.33g) recorded in 1 November sown crop (M_1) might be due to optimum weather conditions coupled with more number of growth days during reproductive stage which might have helped in transformation of more assimilates into grains and subsequently develop to in to bold grain during early sowing, whereas, with delay in sowing, higher temperature and lesser growth days during reproductive stages might have reduced the grain development. Higher grain weight cob^{-1} (109.3 g) in early sown crop could be attributed to cumulative effect of more number of grains cob^{-1} and higher 1000-grain weight, whereas, a significant decrease in grain weight cob^{-1} with delayed sowing might be due to less number of cobs and grains cob^{-1}.

Higher grain yield (32.14 q ha^{-1}) was observed in 1 November (M_1) sown crop which was significantly superior over others date of sowing. Grain yield was reduced with subsequent delay in sowing of the crop. Reduction in the crop yield might be due to adverse effects of weather parameters particularly rainfall, temperature and relative humidity on the growth and development of the crop. Generally, environmental variable may over ride genetic influences and as such variations in meteorological parameters at different date of sowing exert their influence on the plant growth and ultimately yield. The results are in close conformity with Casini (2012) [5] who reported significant differences among planting dates for ear plant^{-1} and grain yield of maize. Sen *et al.* (2000) [16] also reported decreased grain yield due to delay in sowing time in maize.

Data (Table 2) indicates that nitrogen management practices brought about significant variation in respect of yield attributes and yield. Higher number of grains cob^{-1}, 1000 -grain weight and grain weight cob^{-1} was obtained with the application of 50% N as inorganic +1.0 t ha^{-1} V.C. (N_3) which was significantly superior over other nitrogen management. This might be due to more availability of nutrients from the application of vermicompost in combination with 50 per cent inorganics throughout the growing season. The results are in close conformity with Zaremanesh *et al.* (2017) [20]. However the treatment 50% N as inorganic +1.0 t ha^{-1} V.C. (N_3) was statistically at par with 75% N as inorganic + 0.5 t ha^{-1} V.C. (N_2) with respect to yield attributes.

Application of 50% N as inorganic + 1.0 t ha^{-1} V.C. (N_3) recorded significantly higher grain yield (31.05 q ha^{-1}) compared to other nitrogen treatments. This might be due to higher number of grains cob^{-1} and 1000-grain weight in the treatments receiving nutrients from both of the sources in equal proportion (50:50) than their individual applications. Combined application of both sources of nutrient might have resulted in better availability of nutrients throughout the crop growth period. The results are in close conformity with Nagavani and Subbian (2014) [11] and Endris and Dawid (2015) [8].

Agro meteorological indices

Accumulated growing degree days (AGDD)

Data (Table 3) show that microclimatic regimes brought about significant variation in accumulated GDD at all phenological stages of maize. AGDD decreased with successive delay in sowing time to attain different growth stages. AGDD to attain tasseling, silking and physiological maturity from sowing was 703°C days, 738°C days and 905°C days respectively in 1 November sown crop (M_1). On the other hand, 15 December sown crop (M_4) accumulated 657°C days, 684°C days and 795°C days to attain tasseling, silking and physiological maturity stages, respectively. The results are in agreement with the findings of Praveen *et al.* (2018) [14] where they found that wheat crop sown on 5th November utilised more heat units as compared to 15th November and 25th November sown crops. The shortening of the duration of the crop sown late was due to forced maturity because of higher temperature during reproductive phase of the crop.

Accumulated helio-thermal units (AHTU)

Data (Table 3) indicated that microclimatic regimes brought about significant variation in accumulated HTU at all phenological stages of maize. The crop sown on 1 November (M_1) accumulated more HTU of 5118°C day hour to attain tasseling stage, 5368°C day hour to attain silking stage and 6785°C day hour to attain maturity stage, respectively. On the other hand, the crop sown on 15 December (M_4) accumulated less HTU of 4784°C day hour to attain tasseling, 4972°C day hour to attain silking and 5999°C day hour to attain maturity stage, respectively. Accumulated HTU decreased with successive delay in sowings to attain different phenological stages. This might be due to exposure of the crop to lower temperature regimes with delayed sowing. The decreasing trends of thermal units with delayed sowing also reported by Gupta *et al.* (2017) [9] in mustard and Praveen *et al.* (2018) [14] in wheat crop.

Table 1: Days to different phenological stages of maize as influenced by microclimatic regimes and nitrogen management (Pooled of 2016-17 and 2017-18)

Treatments	Tasseling	Silking	Maturity
Microclimatic regimes (M)			
M_1 (1 November)	78	83	115
M_2 (15 November)	76	81	109
M_3 (1 December)	73	78	106
M_4 (15 December)	70	75	99
S.Em.(±)	0.14	0.20	0.37
CD (0.05)	0.28	0.42	0.77
Nitrogen management (N)			
N_1 (100% N as Inorganic)	75	80	109
N_2 (75% N + 0.5 t ha^{-1} V.C.)	75	80	108
N_3 (50% N + 1.0 t ha^{-1} V.C.)	74	79	107
N_4 (25% N + 1.5 t ha^{-1} V.C.)	74	79	105
S.Em.(±)	0.14	0.20	0.37
CD (0.05)	NS	NS	NS

Table 2: Yield and yield parameters of maize as influenced by microclimatic regimes and nitrogen management (Pooled of 2016-17 and 2017-18)

Treatments	No of grains cob^{-1}	1000-grain weight (g)	Grain weight cob^{-1} (g)	Grain yield (q ha$^{-1)}$
Microclimatic regimes (M)				
M_1(1 November)	300.7	224.33	109.3	32.14
M_2 (15 November)	292.1	222.16	107.8	28.97
M_3 (1 December)	273.4	218.32	103.0	26.40
M_4 (15 December)	250.0	212.13	98.1	25.41
S.Em. (±)	2.9	0.73	0.57	0.18
CD (0.05)	6.0	1.49	1.16	0.53
Nitrogen Management (N)				
N_1 (100% N as Inorganic)	280.0	217.44	103.2	27.73
N_2 (75% N + 0.5 t ha^{-1} V.C.)	287.7	222.14	106.5	29.08
N_3 (50% N + 1.0 t ha^{-1} V.C.)	292.1	223.51	107.7	31.05
N_4 (25% N + 1.5 t ha^{-1} V.C.)	256.4	213.86	100.9	25.06
S.Em.(±)	2.9	0.73	0.57	0.18
CD (0.05)	6.0	1.49	1.16	0.53

Table 3: Accumulated growing degree days (AGDD) and accumulated helio-thermal units (AHTU) at different phenological stages of maize (Pooled of 2016-17 and 2017-18)

Treatments	Tasseling	Silking	Maturity
	AGDD (°C day)		
Microclimatic regimes (M)			
M_1 (1 November)	703	738	905
M_2 (15 November)	692	725	858
M_3 (1 December)	673	705	836
M_4 (15 December)	657	684	795
S.Em.(±)	0.8	1.2	2.3
CD (0.05)	1.5	2.3	4.8
Nitrogen Management (N)			
N_1 (100% N as Inorganic)	683	716	851
N_2 (75% N + 0.5 t ha^{-1} V.C.)	683	715	852
N_3 (50% N + 1.0 t ha^{-1} V.C.)	680	712	851
N_4 (25% N + 1.5 t ha^{-1} V.C.)	679	709	840
S.Em. (±)	0.8	1.2	2.3
CD (0.05)	NS	NS	NS
	AHTU (°C day hour)		
Microclimatic regimes (M)			
M_1 (1 November)	5118	5368	6785
M_2 (15 November)	5049	5266	6386
M_3 (1 December)	4881	5110	6233
M_4 (15 December)	4784	4972	5999
S.Em.(±)	2.8	6.1	8.3
CD (0.05)	5.8	12.4	16.9
Nitrogen Management (N)			
N_1 (100% N as Inorganic)	4966	5182	6354
N_2 (75% N + 0.5 t ha^{-1} V.C.)	4959	5183	6354
N_3 (50% N + 1.0 t ha^{-1} V.C.)	4954	5178	6354
N_4 (25% N + 1.5 t ha^{-1} V.C.)	4953	5172	6343
S.Em. (±)	2.8	6.1	8.3
CD (0.05)	NS	NS	NS

Conclusion
From the study it can be concluded that sowing of *rabi* maize on 1 November with the application of 50% N as inorganic along with vermicompost @ 1.0 t ha^{-1} proved to best for achieving higher yield under Upper Brahmaputra Valley Zone of Assam.

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