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Research Paper

Response of maize (*Zea mays*) hybrids to spatio-temporal variation in planting

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ABSTRACT

A field experiment was conducted during the winter season of 2014–15 and 2015–16 at farmer's field of Madandanga village under Chakdaha Block of Nadia district in West Bengal, to study response of maize (*Zea mays* L.) hybrids to spatio-temporal variation in planting. The experiment was laid out in a split split-plot design with 3 genotypes, viz. ('P 3533', 'P 3396', 'P 30V92') in main plot, 3 planting densities (55,555, 66,666 and 83,333 plants/ha) in sub-plot and 3 sowing dates (20 November, 30 November, 10 December) in sub sub-plots, replicated thrice. Irrespective of planting density and sowing date, the genotype 'P 30V92' gave the maximum yield, followed by 'P 3396' and 'P 3533'. Significantly maximum grain of 12.51 t/ha and stover yield of 12.86 t/ha were obtained in high-density planting (83,333 plants/ha) accounting for 110% and 71% more than low planting density (55,555 plants/ha), respectively. The maximum grain yield of 10.03 t/ha and stover yield of 11.22 t/ha were obtained from 20 November-sown crop; accounting 30% and 24% more grain and straw yields than that derived from late sown (10 December) crop. Economic assessment in terms of gross returns, net returns and benefit: cost ratio showed that the growing maize hybrid 'P 30V92' on 20 November at a density of 83,333 plants/ha proved profitable and hence recommended as a best crop-management practice in the winter season of West Bengal.

***Key words*:** Growth, Nutrient uptake, Phenophases, Thermal parameters, Yield

In West Bengal, cultivation of maize (*Zea mays* L.) during winter is considered to be a best alternative to wheat owing to its high yield potential under assured irrigation facilities (Ray *et al.,* 2018). Interest in maize cultivation in the state has increased considerably over past few decades owing to its growing demand for the grains for human nutrition and livestock feeds. Presently, its cultivation has shifted from subsistence to commercial crop on which many agro-based industries depend for raw materials. Grain yield of maize has steadily increased over the last century because of both genetic improvement and agronomic management such as planting of hybrids, modification of planting dates, maintaining optimum plant density, judicious nutrient management, irrigation, etc. (Banerjee *et al.,* 2014). However, the agronomic management of the crop was neither up to the mark nor developed especially for single-cross hybrids (SCHs). Moreover, the present productivity of maize in West Bengal (4.92 t/ha) although comparatively higher than national average (2.51 t/ha), it is markedly low with respect to global average productivity of 5.11 t/ha (FAOSTAT, 2018).

There is a need to bridge the gap between the existing and potential yield of maize. Hence, selection of suitable hybrids, optimum dates of planting and optimum plant stand are the key factors that can guarantee maize yield potential and stability (Mandal *et al*., 2014). Within the genetic limits, time of sowing is a key factor affecting the productivity of most of the arable crops including maize, owing to changes in the environmental conditions to which phenophases of crops are exposed (Banerjee *et al.,* 2014). In West Bengal, winter (*rabi*) maize is normally sown during the second fortnight of November. Sometimes, its sowing is delayed depending on the withdrawal of monsoon and late harvest of preceding *kharif* crop (rice), which may lead to poor seed yield. Hence maize crop (with suitable variety) must be grown on an optimum sowing date for best utilization of moisture, nutrients and solar radiation. Furthermore, the choice of spatial arrangement of plants, resulting from the combination of row spacing and the number of plants/unit area is one of the most important practices/techniques used to obtain higher maize yield.

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Maize is more affected by variations in plant density than other members of grass family. Moreover, the optimum plant population varies among hybrids and generally is higher in modern stay-green hybrids (Tokatlidis and Koutroubas, 2004). Thus, it is imperative to develop and optimize the planting density for avoiding excessive crowding and thereby enabling the plants to utilize resources (land, light and other resources) more effectively and efficiently (Quanqi *et al.,* 2008).

Since a meagre information is available on the behaviour of maize to these factors in West Bengal for large-scale commercial cultivation of the crop, there is need to fine tune the optimum plant population per unit area for attaining maximum possible yield from the SCHs under irrigated condition. With the development of new varieties, it becomes essential to test them at different sowing dates to exploit their yield potential. With this background, in the present study, it is hypothesized that a good cultivar under modified environment of different sowing dates and maintenance of optimum plant population may help in realizing optimum yield level for maize.

MATERIALS AND METHODS

A field experiment was conducted at farmer's field of Madandanga village under Chakdaha Block of Nadia district in West Bengal (23°26.010' N, 88°22.221' E and 12.0 m above mean sea-level) under typical sub tropical climate. The maximum and the minimum temperature fluctuated between 37.3°C and 24.8°C and 20.3°C–9.6°C during 2014–15 and 35.1°C and 23.7°C and 21.8°C and 9.3°C during 2015–16. The relative humidity prevailed between 89% and 34% in 2014–15, and 97% and 34% in 2015–16. The rainfall receipt during the experimental period (November to March) was 24.2 mm (5 rainy days) during 2014–15 and 112.3 mm (14 rainy days) during 2015-16. The mean daily bright sunshine was recorded as 7.2 hours in winter of 2014–15 and 5.7 hours in winter of 2015–16. Conclusively, weather conditions were quite congenial for growth and development of maize during both the years. The soil was clay loam, having *p*H 7.30, organic carbon 0.42%, available N 104.0 kg/ha, available P 52.5 kg/ha and available K 268.0 kg/ha.

The experiment was laid out in split split-plot design with 3 genotypes ('P3533', 'P 3396', 'P 30V92') in main plot, 3 planting densities (55,555, 66,666 and 83,333 plants/ha) in sub-plot and 3 sowing dates (20 November, 30 November, 10 December) in sub sub-plots, with 3 replications. Seeds were hand-planted at a spacing of 60 cm × 30 cm (55,555 plants/ha), 75 cm × 20 cm (66,666 plants/ha) and 60 cm × 20 cm (83,333 plants/ha). Thus, the experiment comprised 27 treatment combinations (3 × 3 × 3) replicated thrice. Individual plots were 4 m × 5 m wide. In both the years of study, seeds of tested maize hybrids were sown with a seed rate of 25 kg/ha on specific date, maintaining desirable planting density (as per treatment details). Seeds were dibbled (hand-planted) in rows having an east-west orientation at 2 seeds/hill at 3 cm–5 cm depth. The crop was thinned down to 1 plant/hill to maintain the desired plant population at 3-leaf stage (V_3). Recommended dose of fertilizer (RDF) i.e. 200, 25.8 and 49.8 kg N, P and K/ha (Ray *et al.*, 2018), respectively was given through urea (46% N), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O). All P and K fertilizers are applied to the soil before to sowing in each plot. The N fertilizer were applied in 3 splits–40% before sowing, 30% at 30 days after sowing (DAS) at knee-height stage and rest 30% at pre-tasseling stage. Light irrigations were given at 5 days interval within 12 DAS for good germination and better crop establishment. Then 3 irrigations were given at an interval of 7–8 days, maintaining water level below two-third height of the ridges. Irrigation was completely withheld 10 days before harvesting of the crop. Two manual weedings (at 30 and 60 DAS) were as given to the plots to promote early crop growth, and ridges were made by manual labour with the help of spade. In the first year, ready-mix formulation of Chloropyriphos 50% + Cypermethrin 5% (Hamla 550) was applied @ 2 ml/litre water to control the borer at initial crop-growth stage. In addition, Lamda Cyhalothrin (Agent Plus 5 EC) @ 10 ml/15 litre water was applied 65 DAS to get rid of the problem of grasshopper. But in the second year, the crop was free from pest and disease attack. Crop was harvested when husks turned yellow, silks got a brownish, and grains became hard.

The most common temperature indices used to estimate plant development are growing degree-days (GDD), photo-thermal unit (PTU), helio-thermal unit (HTU), photo-thermal index (PTI) and heat-use efficiency (HUE) and were calculated as per formula given by Singh *et al.* (2014).

$$GDD = \sum_{i=1}^{n} \frac{T_{max} + T_{min}}{2} - T_b$$

where $T_{max\ and}$ T_{min} are daily maximum and minimum temperature; T_b is the base temperature (10°C); n is the number of days required to attain specific phenological stages

PTU (degree – days hours) = GDD × Day length

HTU (degree - days hours) = GDD× Duration of sunshine hours

$$\text{PTI (degree – days/day)} = \frac{\text{GDD}}{\text{Growth days}}$$

$$HUE\ (kg/ha\ degree - days) = \frac{Seed\ yield\ (kg/ha)}{GDD}$$

Plant samples from each treatment were collected, oven-dried, and ground for analyzing total recoveries of N, P and K at harvesting, as per standard methods (Ray *et al.*, 2018). For determination of nutrient (NPK) status of post-harvest soil, standard procedures were followed. The economic assessment in terms of net returns and benefit: cost (B : C) ratio of maize cultivation was worked out based on prevailing market prices of inputs and outputs.

The data obtained on different growth parameters, yield components, yield, nutrient uptake and soil-nutrient status were analyzed statistically by the method of analysis of variance (ANOVA) as per the procedure outlined for split-split plot design (Gomez and Gomez, 1984). Statistical significance was tested by P-value at 0.05 level of probability and critical difference (CD) was worked out wherever the effects were significant.

RESULTS AND DISCUSSION

Growth parameters

Irrespective of planting density and sowing date, tested genotypes exhibited non-significant ($P \geq 0.05$) variation among themselves in terms of plant height, leaf area index (LAI) and crop-growth rate (CGR) during 90–120 days after sowing (Table 1). Only the dry-matter accumulation (DMA) at time of harvesting differed significantly among the genotypes. The genotype 'P 30V92' recorded the maximum DMA, accounting 10% more than that of 'P 3533'; being statistically at par with DMA in 'P 3396'. Planting density exerted significant influence on all the measured growth attributes (Table 1). Plants showed significantly maximum height, LAI, DMA and CGR in high density planting (83,333 plants/ha), accounting 8, 40, 12 and 69% more than low planting density (55,555 plants/ha) respectively. The lack of negative effect of increasing plant density on measured growth attributes was probably because it had not increased expressively the intra-specific competition (Balem *et al.,* 2014). When crops are planted at high densities, the efficiency of light interception is improved as a consequence of increased LAI. Such increase may be due to early canopy closure, improving light interception (Kamara *et al.,* 2018). Moreover, an increase in plant density increases the biomass because of better use of soil and moisture (Mokhtarpour *et al.,* 2013). This may further be attributed to increased completion for light (Dawadi and Sah, 2012). In the present study, sowing date significantly ($P \leq 0.05$) influenced only plant height and LAI (Table 1). Maize plants were the tallest with greater LAI when sown on 20 November, accounting 4% higher height and 9%

Table 1. Effect of genotype, planting density and sowing date on growth attributes of winter (*rabi*) maize, plant nutrient uptake and available nutrient status in post-harvest soil (pooled mean data of 2 years)

Treatment	Plant height (cm) at harvesting	LAI at harvesting	DMA (g/plant) at harvesting	CGR ($g/m^2/day$) at 90–120 DAS	N uptake (kg/ha)	P uptake harvest (kg/ha)	K uptake (kg/ha)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Genotype										
'P 3533'	266	5.60	238.2	24.9	368.6	18.8	210.4	134.2	31.7	238.7
'P 3396'	260	5.87	255.5	30.1	372.1	20.6	230.2	122.7	30.5	232.8
'P 30V92'	263	5.70	262.5	30.6	387.5	19.9	210.0	131.7	41.0	216.4
SEm±	2.52	0.10	8.15	2.21	15.35	0.58	11.82	11.28	2.875	11.79
CD (P=0.05)	NS	NS	23.15	NS	NS	1.65	NS	NS	8.165	NS
Planting density										
55,555 plants/ha	253	4.80	238.5	22.1	268.3	13.1	140.6	147.5	40.4	246.8
66,666 plants/ha	263	5.64	250.0	26.0	363.7	19.0	206.7	127.6	33.6	226.6
83,333 plants/ha	272	6.73	267.7	37.4	515.8	28.7	321.7	113.4	29.1	214.4
SEm±	2.87	0.13	5.02	1.59	11.72	0.96	11.24	5.72	1.89	8.17
CD (P=0.05)	8.16	0.37	14.26	4.52	33.27	2.71	31.90	17.39	5.39	23.20
Sowing date										
November 20	267	5.97	237.2	28.2	444.7	21.9	243.9	134.6	38.6	240.3
November 30	264	5.74	231.6	28.4	355.6	19.2	211.0	129.7	35.6	237.7
December 10	257	5.47	225.1	29.0	328.2	18.2	195.3	124.3	28.9	209.9
SEm±	2.87	0.13	5.02	1.59	11.72	0.96	11.24	5.72	1.89	8.17
CD (P=0.05)	8.15	0.37	NS	NS	33.27	2.71	31.90	NS	5.39	23.20

LAI, leaf area index; DMA, dry matter accumulation; CGR, crop growth rate; DAS, days after sowing; NS, non-significant

Genotype × planting density, Genotype × sowing date and planting density × sowing date interaction effects were non-significant for all the parameters higher LAI than the values obtained with plants sown late (10 December). Late planting of maize might have experienced the effect of uncongenial low and high temperature coincided with the growth and reproductive phases, respectively, and finally resulted in untimely and forced maturity, and thus realized lower growth attributes (Singh *et al.*, 2016). In the present study, the interaction effects were found non-significant for all the measured growth attributes.

Nutrient uptake by crop at physiological maturity

Uptake of N and K by maize plants remained unaffected by genotype factor (Table 1), but P uptake was significantly ($P\leq0.05$) higher in 'P 3396'. Planting density had significant effect on crop NPK uptake, and it was the maximum with higher density of 83,333 plants/ha, accounting 92, 119 and 129% more than low planting density (55,555 plants/ha) respectively. Rao *et al.* (2014) reported higher uptake of NPK when the crop raised at higher density (83,333 plants/ha) compared with lower planting density. In the present study, NPK uptake in maize plant varied significantly ($P\leq0.05$) under the influence of sowing date (Table 1). Early sowing of maize hybrids was superior to late sowing; as 20 November-sown plants recorded higher N, P and K uptake in above-ground biomass, accounting 35, 20 and 25% more than 10 December-sown plants respectively. Better nutrient uptake, as observed in early-sown crop, was owing to development of efficient root-system, better absorption and translocation of water and NPK, interception of solar radiation and assimilation of carbon dioxide (Yadav *et al.,* 2009). In the present study the interaction effects failed to record any significant variation on NPK uptake in tested maize varieties.

Available nutrient status of post-harvest soil

Available N and K status in soil was not much affected by genotype factor. However, the type of genotype exerted significant influence only on available P content of post-harvest soil (Table 1), and it was the maximum in plots occupied by the 'P 30V92', followed by the plots of 'P 3533' and 'P 3396'. Different planting densities had significant effect on the available NPK content in post-harvest soil. The available NPK content in plots decreased as the planting density increased and the maximum available N, P and K content were observed at low density (55,555 plants/ha), accounting 30, 39 and 15% more than higher planting density (83,333 plants/ha) respectively. This might be owing to progressive increase of NPK uptake by the crop which ultimately reduced the available status of those nutrients in post-harvest soil under higher plant density. In the present study, the changes in sowing dates of tested maize genotypes caused significant variation in available P and K con-

Table 2. Effect of genotype, planting density and sowing date on yield components, yield and economics of winter maize (pooled mean data of 2 years)

Treatment	Cobs/ plant	Cob length (cm)	Cob girth (cm)	Grain rows/cob	Grains/ row	1,000-grain weight (g)	Grain yield (t/ha)	Stover yield (t/ha)	Gross returns (× 10³₹/ha)	Net returns (× 10³₹/ha)	Benefit: cost ratio*
Genotype											
'P3533'	1.2	19.4	14.7	14.5	36.5	317.6	8.76	10.22	132.32	56.62	1.72
'P3396'	1.1	18.7	14.6	14.4	34.9	322.4	9.02	9.76	136.78	59.98	1.78
'P30V92'	1.1	18.9	14.8	14.4	35.4	325.2	9.35	10.26	142.07	66.37	1.88
SEm±	0.05	0.20	0.14	0.18	1.19	3.14	0.23	0.33	2.30	1.29	0.03
CD (P=0.05)	NS	0.57	NS	NS	NS	NS	NS	NS	6.54	3.67	0.09
Planting density											
55,555 plants/ha	1.1	19.0	14.6	14.5	35.5	321.2	5.93	7.52	92.13	17.33	1.23
66,666 plants/ha	1.3	19.5	15.0	14.9	37.6	332.8	8.69	9.86	132.69	50.49	1.74
83,333 plants/ha	1.0	18.5	14.4	13.9	33.6	311.3	12.51	12.86	188.35	109.45	2.38
SEm±	0.06	0.22	0.14	0.17	0.95	3.79	0.24	0.27	2.47	1.99	0.14
CD (P=0.05)	0.16	0.62	0.40	0.49	2.70	10.76	0.67	0.78	7.02	5.66	0.40
Sowing date											
November 20	1.2	20.1	15.2	14.4	37.1	330.9	10.03	11.22	152.83	76.13	1.99
November 30	1.1	18.9	14.5	14.6	35.6	324.1	9.41	9.96	142.25	65.55	1.85
December 10	1.1	18.0	14.4	14.3	34.1	310.2	7.68	9.07	117.98	41.28	1.53
SEm±	0.06	0.22	0.14	0.17	0.95	3.79	0.24	0.27	2.47	1.99	0.14
CD (P=0.05)	NS	0.62	0.39	NS	2.70	10.76	0.67	0.78	7.02	5.66	0.40

NS, non-significant; NB: Selling price of maize grain ₹13/kg; selling price of maize stover ₹2/kg; *B:C ratio, Benefit: cost ratio; gross returns/total cost; NS, non-significant; Genotype × planting density, Genotype × sowing date and planting density × Sowing date interaction effects were non-significant for all the parameters tent only (Table 1). The available soil P and K content in post-harvest soil increased in plots of early sown crop (20 November), accounting 34 and 14% more than late sown crop (10 December) respectively. At early sowing, optimum plant population stand resulted in proper utilization of the soil resources which ultimately resulted in higher positive residual effect (Jat *et al.,* 2017). The higher above and below ground biomass production in maize by optimum population and improved nutrition might have resulted in enhanced NPK in post-harvest soil (Kumar *et al.,* 2015). Taller growth of early planted crop with optimum population may augment the crop's ability to suppress weeds. Hence, soil NPK mining by weeds was less, resulting in greater NPK availability of post-harvest soil. In contrary, fewer slow emerging leaves of late planted crop with under-crowded population resulted in a less-dense crop canopy and shorter plants. Consequently, more light would be available to weeds, causing greater NPK mining leaving lower NPK status of post-harvest soil (Williams, 2008).

Yield components of hybrid maize

Irrespective of planting density and sowing date, the tested genotypes exhibited significant variation in cob length only (Table 2), and it was significantly higher in 'P 3533' than the other genotypes. Other yield components, namely cobs/plant, cob girth, grain rows/cob, grains/row and 1,000-grain weight were also unaffected by variety factor (Table 2). All these measured yield components of tested cultivars varied significantly ($P \leq 0.05$) when sown under varied planting densities. The maximum cobs/plant, cob length, cob girth, grain rows/cob, grains/row and 1,000-grain weight were obtained in plants grown under medium planting density (66,666 plants/ha), accounting 18, 3, 3, 3, 6 and 4% more than the values obtained under low planting density (55,555 plants/ha) respectively. Significant influence of planting geometry on yield components was reported earlier by Kar *et al.* (2006); however, they found greater yield components at low planting density (55,555 plants/ha). In the present study, the change in sowing dates brought about significant variation in cob length, cob girth, grains/row and 1,000-grain weight of the genotypes, but the variation was non-significant in cobs/plant and grain rows/cob (Table 2). Plants sown early (20 November) produced cob with greater length and girth, accounting 12 and 6% more than the values obtained with late (10 December)-sown plants respectively. The higher number of grains/row and 1,000-grain weight were obtained with the plants sown on 20 November, accounting 9 and 7% more than that obtained by 10 December-sown plants respectively; being statistically at par with the plants planted on 30 November. The inferior yield attributes observed in delayed planting may be due to the short period of vegetative growth and the adverse weather conditions, such as temperature and monthly precipitation, which did not match with the optimum degree for the reproductive stages. Hence, low levels of photosynthetic products might have been accumulated in case of late-sown plants (Kamara *et al.,* 2018). In the present study, the interaction effects were non-significant on all the measured yield components.

Yield and profitability

Irrespective of planting density and sowing date, the variations in grain and stover yield among tested genotypes ties were non-significant (Table 2). Both grain and stover yields were significantly affected by planting density. The significantly maximum grain (12.51 t/ha) and stover yield (12.86 t/ha) were obtained in high density planting (83,333 plants/ha), accounting 110 and 71% more values than low planting density (55,555 plants/ha) respectively. This plant population represents the minimum stress condition, under which the maximum yield is expected. In addition, parallel to the increasing plant density, the individual production of plants decreases but the yield per unit area increases (Kar *et al.*, 2006). In the present study, sowing date significantly influenced grain and stover yields (Table 2). The maximum grain and stover yields were obtained from 20 November-sown plants; being 30 and 24% more than grain and straw yields derived from late-sown (10 December) plants. This result was achieved because late sowing de-

Table 3. Growing degree-days (GDD), photo-thermal unit (PTU), helio-thermal unit (HTU), photo-thermal index (PTI) and heat-use efficiency (HUE) required for some specific phenophases in maize hybrids under different sowing dates (pooled mean data of 2 years)

Sowing dates	GDD (degree-days)			PTU (degree-days hour)			HTU (degree-days hour)			PTI (degree-days/day)			HUE (kg/ha degree-days)
	DFPT	DFPS	DM	DFPT	DFPS	DM	DFPT	DFPS	DM	DFPT	DFPS	DM	
20 November	962	996	1,748	10,607	10,998	19,959	4,932	5,183	10,890	7	7	12.5	9
30 November	962	1,013	1,770	10,607	11,205	20,221	4,932	5,328	11,018	7	7.5	12.5	8.5
10 December	953	997	1,781	10,679	11,013	20,352	4,947	5,194	11,043	7	7.5	12.5	8

DFPT, Days to 50% tasseling; DFPS, days to 50% silking; DM, days to maturity creased the aerial growth of the crop and poor grain-filling because of low heat-use efficiency (HUE). In present study, the interaction effects failed to record significant variation in grain and stover yields of tested maize genotypes.

The economic benefit of hybrid maize cultivation was observed to vary with studied factors, namely genotypes, planting density and sowing date (Table 2). Irrespective of planting density and sowing date, the genotypes 'P 30V92' recorded the maximum gross return (142.07 × 10^3 ₹/ha), net return (66.37 × 10^3₹/ha) and benefit: cost (B:C) ratio (1.88), followed by genotypes 'P 3396' and 'P 3533'. The maximum gross returns (188.35 × 10^3₹/ha), net returns (109.45 × 10^3₹/ha) and B : C ratio (2.38) were recorded with the crop grown at higher density (83,333 plants/ha), accounting 104, 531 and 93% more over the crop planted at lower planting density (55,555 plants/ha), respectively. The greater response in gross returns (152.83 × 10^3 /ha), net returns (76.13 × 10^3₹/ha) and B : C ratio (1.99) were recorded in crop sown early (20 November), accounting 29, 84 and 30% more over the crop sown late (10 December) respectively (Table 2).

Thermal requirement for some specific phenophases

The photo-thermal index (PTI) calculated for different phenophases (days to 50% tasseling, days to 50% silking and days to maturity) did not exhibit any variation for tested maize genotypes sown at different time interval (Table 3). The thermal requirement parameters recorded at 50% tasseling date showed that growing degree-days (GDD), photo-termal unit (PTU), helio-thermal unit (HTU) and PTI values did not vary for the crops sown on 20 November and 30 November. However, the values for all the thermal parameters recorded for late-sown crop (10 December) were comparatively less. At 50% silking, the values of GDD, PTU, HTU and PTI were comparatively less for early-sown crop (20 November) than late-sown one. Similarly, the values of GDD, PTU and HTU recorded at physiological maturity found were less in early-sown crop (20 November), and the values increased progressively with successive delay in sowing. Increase in above thermal indices under late-sowing indicated that the crop used less heat units under crop sown early rather than late-planted crop (Devi *et al.,* 2019). In the present study, the early-sown crop had the highest heat-use efficiency (HUE) and it decreased with delay in sowing following trend 20 November > 30 November > 10 December (Table 3). Reduction in HUE under late-sown conditions designates that the crop used heat more efficiently under early crop as compared to late-sown conditions (Singh *et al.,* 2014; Devi *et al.,* 2019).

Summarizing all, it is understood that the sustainable productivity of maize could be achieved through sowing suitable variety at proper time with optimum plant population. Thus, it can be inferred that sowing of maize genotypes 'P 30V92' or 'P 3396' on 20 November at a density of 83,333 plants/ha can be recommended as a best crop management practice for sustainable and profitable maize production in winter (*rabi*) season of West Bengal.

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