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Effect of row spacing and mulching in the growth and growth attributes of maize (*Zea mays* L.) In the eastern Uttar Pradesh

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Abstract
Maize is the one of the most important staple food crops amongst all of the cereal crops used in most of the country worldwide and that is why it's known as the "queen of the cereals". This is because of its very high nutritive values and especially protein for humans and animals (livestock). This crop can grow in the extremely diverse environments of India as well as the world. Observant of its impotence, a field experiment was carried out under a split-plot design with three levels of row spacing *i.e.*, S_1, S_2, and S_3, and four levels of mulching *i.e.*, no mulch (M_0), paddy straw mulch (M_1), green weed mulch (M_2) and dust mulch (M_3). The study was done to assess the impact of row spacing and mulching on the growth attributes of the maize. The plant height plant^{-1} and the number of levees plant^{-1} of the treated crop produced significantly higher growth attributes due to the effect of row spacing and mulching treatments. The significant treatment response was chronicled in the descending order for the row re-spacing as $S_3 > S_2 > S_1$ at 60 DAS and harvesting time during both the year of experimentation but the data at 30 DAS gave a non-significant response. The mulching treatment was chronicled in the descending order $M_2 > M_3 > M_1 > M_0$ during both the year of experimentation and was observed significant response among themselves at all the levels of observation. The data, in the case of the plant dry matter, was noticed in the ascending order and can chronicle for row re-spacing as $S_1 > S_2 > S_3$, and for mulching it was in the descending order $M_1 > M_2 > M_3 > M_0$ which was significant during both the years of experimentation. Similar results were also obtained with pooled data analysis. The interaction effect was like a copy of the results obtained above. The higher plant height and number of leaves were found in descending order with wider row spacing might be due to better aeration and sufficient radiation for plant photosynthesis resulted increased the growth of tested crop and higher plant dry weight was may be due to an increase in the plant populations between the row spacing and mulching.

Keywords: Row spacing, mulching, maize, and growth

Introduction
The maize (*Zea mays* L.) is one of the most important cereal grain crops in the world. Maize is produced throughout India in diverse environments and it is also the third-leading cereal crop after wheat and rice in the world. This can grow all over of the world under the various diversity of soils, climates, biodiversity, and management practices which is contributing to 37% produced 30 global grain productions worldwide. The maize crop is a warm-weather crop and grows right from sea level to over 3000 m altitudes. It requires adequate moisture and warmth from sowing to the end of flowering. The optimum temperature for germination is 21 ^{o}C, while for growth it is 32 ^{o}C. Its production in the last decade was 16.64, 16.49, 16.20, 17.15, 17.01, 16.05, 18.92, 20.12, 19.41, 19.43, and 291.56 million MT started from the year 2010-11 to 2020-21, respectively (Ministry of Agriculture and Farmers Welfare) [1].

Water is now the most important natural resource as compared with other available natural resources. The water deficit and its importance are well known and are one of the thrust areas for researchers. Therefore, several kinds of research already had been done and gowning on to save/conserve water for the future generation. In this line, the present research was conducted with the objective of judicious use of water without any loss of production of the maize.

The objective is to achieve soil, water, and energy preservation decided with suitable row spacing and mulching on the surface of maize and each operation is planned to maintain soil sheltered by the residues or growing plants used as mulch material. The mulching practices may improve the properties of soil such as increasing organic matter in soil and reducing soil erosion. Mulching through plant residues can changes soil properties in ways that affect plant growth, and reduce water runoff from fields. The mulched soil is cooler and the soil surface under the residue is moist, as a result, soil moisture may conserve up to the optimum level of maize production (Rina *et al*., 2020; Dutta *et al*., 2015; Bharud *et al*., 2014; Naik *et al*., 2012; Enujeke *et al*., 2013) [2, 3, 4, 5, 6].

Materials and Methods

The study was carried out at the Agricultural Research Farm of the S.D.J.P.G. College, Chandeswar, Azamgarh, Uttar Pradesh (India) during *Kharif* season of 2019 and 2020. This is situated geographically at 26˚.4' North latitude, 83º. 11' East longitudes, 92.60 meters above mean sea level in the sub-humid eastern plain zone. The maximum temperature in summer is as high as 48.3 ˚C and the minimum temperature in winter falls below 10.7 ˚C. The annual rainfall of the locality was 908.6 mm in the year 2019 and the maximum temperature in summer is as high as 45 ˚C and the minimum temperature in winter falls below 12 ˚C. The annual rainfall of the locality was 854.1 mm in the year 2020.

The experiment was laid out in a split-plot design having three replications. Soil analysis was done before the sowing of the crop and after the harvesting of the crop. The plot size was 5 m X 4 m for experimentation and the net plot size was 4.5 x 3.5 m and the row spacing was comprised of three-row spacing methods *viz.* 30 cm row spacing (S_1), 45 cm row spacing (S_2), 60 cm row spacing (S_3), and four different mulches *viz.* No mulch (M_0), Paddy straw mulch (M_1), Green weed mulch (M_2), and Dust mulch (M_3). A variety of maize was used 'KANCHAN (K-25)' as experimental material and standard procedures were adopted for recording growth parameters. The mulching material (No mulch, paddy straw mulch, green weed mulch, and dust mulch) was applied in the field after the sowing of the maize. The differences in the treatment mean were tested using the least significant difference (LSD) at a 5% level of probability (Gomez and Gomez, 1976 [7]). The standard procedures were adopted for recording the data of agronomical growth parameters and cultural practices were done is available in Table 1.

Table 1: Schedule of agronomical field operations

S. No.	Operation	Year	
		2019	2020
(A). Pre-sowing operations			
1.	Land preparation	10.07.2019 to 15.07.2019	13.07.2020 to 16.07.2020
2.	Layout and experiment	16.07.2019	17.07.2020
(B). Sowing operations			
1.	Fertilizer application and sowing	17.07.2019	18.07.2020
2.	Allocation of treatment	17.07.2019	19.07.2020
3.	All Mulching	03.08.2019	02.08.2020
4.	Thinning of crop	06.08.2019	08.08.2020
5.	Weeding	10.08.2019	15.08.2020
	1. Hand weeding 2. Hand weeding	02.09.2019	06.09.2020
6.	Harvesting and bundling	22.09.2019	29.09.2020
7.	Threshing and cleaning	05.10.2019	08.10.2020

Results and Discussion

The plant height (Table 2) and the number of leaves plant^{-1} (Table 5) of the maize crop was recorded significantly higher at 60 days after sowing (DAS) and at the harvest amongst themselves due to the effect of the row spacing and mulching. This happened during both the years of the experimentation. Unfortunately, the data at 30 DAS was not able to reach the level of significance. The data clearly showed that the highest mean value of the plant height plant^{-1} and the number of leaves plant^{-1} was recorded at the harvest with the row spacing of the S_3 (60 cm) followed by S_2 and S_1 treatment during both the years and pooled, subsequently. The significant treatment response was chronicled in the descending order for the row re-spacing as $S_3 > S_2 > S_1$ at 60 DAS and a similar sequence was also observed at harvesting time during both the year of experimentations. Unfortunately, the response of row spacing of treated crop at 30 DAS was given non-significant response but simultaneously the response of mulching effect was observed significant among themselves at all the levels of observations. The mulching treatment was chronicled in the descending order $M_2 > M_3 > M_1 > M_0$ during both the year of experimentations at all the levels of observations including pooled data analysis also.

The higher plant height and number of leaves were found in descending order with wider row spacing (60 cm) might be due to better aeration and sufficient radiation for plant photosynthesis resulting in increased growth of the treated crop. The higher plant dry weight may be due to increases in the plant population between the row spacing and mulching. The row spacing treatment in maize crop increases the vegetative growth of the plant up to the harvest. Higher plant height was noted under M_1-paddy straw mulch, this is might be due to the easily available soil moisture which helps to development of a favorable environment for root development and improve the microenvironment for their growth during both the years of experimentation. This is maybe because the paddy straw has a low C:N ratio which is not suitable to easily decompose by the microorganisms. Therefore, the paddy straw mulch might be given a longer time of shelter to the tested crop and was able to restrict the soil moisture loss than the rest of the treatments. The plant leaves and dry matter accumulation were also recorded highest in M_1-paddy straw mulch. The paddy straw mulch particularly restricts the evaporation of water from the soil surface to the atmosphere, which ultimately increases the availability of soil water to the crops resulting in better growth and development of the experimental crop. Nevertheless, the highest plant dry matter accumulation at all the levels of data recorded (Table 8) of the maize reflected opposite results from the plant height plant^{-1} and the number of leaves plant^{-1} of the row spacing and mulching treatments. The effect of the row spacing and mulching was chronicled in the descending order for row re-spacing as $S_1 > S_2 > S_3$ and for mulching, it was $M_1 > M_2 > M_3 > M_0$ which was significant during both the years of experimentation at all the stages and years of plant sampling except 30 DAS in the year of 2019 which was non-significant and the rest values followed similar trend *i.e.* 30, 60 DAS and at the time of harvest and as well pooled data analysis also.

The interaction effect of row spacing and mulching on the plant height of the maize gave significant results amongst themselves at 60 DAS and at the harvest of the crop but this result was not reached up to the level of significance at 30 DAS. The highest plant height plant^{-1} was recorded 210.61, 214.82, and 212.72 cm during 2019, 2020, and pooled data with the interaction between the row spacing and mulching under the treatment of S_3M_1 and an almost similar trend was also recorded at harvest (Table 4). The interaction effect of row spacing and mulching on the plant leaves plant^{-1} was also noticed similar to the plant height except with little variation in the year 2020. The highest number of plant leaves per plant recorded S_3M_1 (22.08, 2019), S_3M_0 (23.43, 2020), and S_3M_1 (21.67, pooled) at 60 DAS (Table 6) which was switched over to S_2M_1 and the number of leaves was obtained 21.34, 21.55, and 21.45 in the year 2019, 2020, and pooled number of plant leaves at the time of harvest (Table 7). Further, the critical observation of the data (Tables 9, 10, and 11), the interaction effect amid the row spacing and mulching, the S_1M_1 was perceived that the plant dry matter accretion was significantly superior over all other treatments at all the stages of

observations (30, 60 DAS, and at harvest) during both the years of the experiment excluding 30 DAS in the year 2019 which reflected different manner than all other treatments of the row spacing and mulching. This was might be due to the decomposition of mulching material in the second year (2020) increasing the water holding capacity of soil as well as efficiently restricting the evaporation loss of soil moisture.

Almost similar results were reported by several researchers and in this, Naik, *et al.* (2012) [5] reported similar results in a field experiment during *Kharif*, 2018 at the Agricultural College Farm, Mahanandi. Rajput, *et al.* (2015) [8] ware conducted a field experiment on the row spacing and mulching effect on the growth (*Zea mays* L.) at Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha Mirzapur, Uttar Pradesh (India) during the *Kharif* season of 2012-13 with the split-plot design which had been three levels of row spacing (30 cm, 45 cm, and 60 cm) and with the four levels of mulching (No mulch, paddy straw mulch, green weed mulch, and dust mulch). They also stated that the paddy straw mulch gave significantly higher plant height (215.06 cm) with the 60 x 20 cm row spacing than the 45 x 20 and 30 x 20 cm planting geometry (Priya and Shashidhara, 2016, Kumar *et al.*, 2016, Pradhan *et al.*, 2018 [11], Verma *et al.*, 2020, Sanders *et al.*, 2017, Verma *et al.*, 2017, and Sidhu *et al.*, 2007) [9, 10, 11, 12, 13, 14, 17].

Table 2: Effect of the row spacing and mulching on the plant height (cm) in the maize crop

Treatment	Plant Height (cm)						Pooled Plant Height (cm)		
	30 DAS		60 DAS		At Harvest		30 DAS	60 DAS	At Harvest
	2019	2020	2019	2020	2019	2020			
Row Spacing									
S_1	97.97	98.34	165.80	170.36	172.40	175.55	98.15	168.08	173.98
S_2	106.62	105.54	173.91	176.46	178.94	179.83	106.08	173.70	179.39
S_3	113.38	114.13	191.23	196.63	199.09	204.09	113.76	193.19	200.68
SEm (±)	0.89	0.88	0.34	0.53	0.71	0.45	0.96	0.66	0.50
LSD (*p*=0.05)	NS	NS	1.34	2.07	2.80	1.78	NS	2.60	1.98
Interaction (R)	NS	NS	Sig	Sig	Sig	Sig	Ns	Sig	Sig
Mulching									
M_0	97.80	98.32	161.97	166.87	169.47	173.61	98.06	164.42	170.34
M_1	113.40	113.40	189.02	192.80	195.84	200.59	113.40	190.91	198.22
M_2	108.56	109.22	181.28	184.29	188.25	189.52	108.89	182.78	188.89
M_3	104.19	103.08	175.66	180.65	180.34	182.24	103.64	175.19	181.29
SEm (±)	0.43	0.31	0.44	0.39	0.76	0.65	0.40	0.52	0.55
LSD (*p*=0.05)	1.26	0.91	1.30	1.15	2.27	1.92	1.20	1.54	1.63
Interaction (M)	Sig	Sig	2.22	Sig	Sig	Sig	Sig	Sig	Sig
Interaction (SxM)	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig
CV%	3.61	2.59	2.22	1.92	3.75	3.12	3.44	2.61	2.68

Table 3: Interaction effect of the row spacing and mulching on the plant height (cm) in the 60 DAS treated *Kharif* sessions maize crop

Treatments	2019				2020				Pooled			
Mulching	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**
M_0	155.07	158.64	172.20	161.97	163.15	161.81	175.64	166.87	159.11	160.22	173.92	164.42
M_1	171.61	184.85	210.61	189.02	175.04	188.55	214.82	192.80	173.32	186.70	212.72	190.91
M_2	168.98	167.83	207.03	181.28	172.36	167.45	213.05	184.29	170.67	167.64	210.04	182.78
M_3	167.56	184.33	175.08	175.66	170.91	188.02	183.02	180.65	169.24	180.25	176.08	175.19
SEm (±) S x M	1.31				1.16				1.55			
LSD (*p*-0.05)	3.90				3.44				4.61			
CV (%)	2.22				1.92				2.61			

Table 4: Interaction effect of the row spacing and mulching on the plant height (cm) of the tested *Kharif* sessions maize crop at harvest

Treatments	2019				2020				Pooled			
Mulching	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**
M_0	164.22	165.05	179.16	169.47	169.74	168.35	182.74	173.61	166.98	166.70	177.33	170.34
M_1	176.08	192.32	219.12	195.84	182.11	196.17	223.50	200.59	179.09	194.24	221.31	198.22
M_2	177.25	172.10	215.39	188.25	179.32	169.55	219.70	189.52	178.29	170.83	217.54	188.89
M_3	172.04	186.29	182.69	180.34	171.04	185.26	190.41	182.24	171.54	185.78	186.55	181.29
SEm (±) S x M	2.29				1.94				1.65			
LSD (p=0.05)	6.81				5.76				4.90			
CV (%)	3.75				3.12				2.68			

Table 5: Assessment of the row spacing and mulching effect on the plant leaves plant^{-1} (cm) amongst treatment of the *Kharif* sessions of the maize

Treatment	Plant Leaves (cm)						Pooled Plant Leaves (cm)		
	30 DAS		60 DAS		At Harvest		30 DAS	60 DAS	At Harvest
	2019	2020	2019	2020	2019	2020			
Row Spacing									
S_1	10.53	10.30	18.23	18.74	18.79	18.28	10.41	18.49	18.54
S_2	10.85	11.07	19.45	20.03	19.46	19.29	10.96	19.74	19.38

S_3	11.27	12.36	19.99	21.68	19.79	21.23	11.81	20.83	20.51
SEm (±)	0.04	0.12	0.07	0.08	0.04	0.03	0.08	0.05	0.05
LSD (p=0.05)	NS	NS	0.27	0.31	0.17	0.12	NS	0.19	0.20
Mulching									
M_0	9.33	10.63	17.73	19.54	18.21	18.87	9.98	18.64	18.54
M_1	11.94	12.07	20.74	20.87	20.41	20.65	12.01	20.80	20.53
M_2	11.46	11.66	19.64	20.37	19.70	19.86	11.56	20.01	19.78
M_3	10.79	10.61	18.78	19.83	19.07	19.01	10.70	19.30	19.04
SEm (±)	0.03	0.04	0.04	0.02	0.02	0.03	0.05	0.04	0.03
LSD (p=0.05)	0.09	0.13	0.13	0.06	0.05	0.09	0.16	0.11	0.08
Interaction (M)	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig
Interaction (SxM)	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig
CV%	2.39	3.55	1.99	0.89	0.78	1.45	4.32	1.72	1.29

Table 6: Interaction effect of the row spacing and mulching on the numbers of plant leaves of the *Kharif* maize crop at 60 DAS

Treatments	**2019**				**2020**				**Pooled**			
Mulching	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**
M_0	16.92	17.26	19.02	17.73	17.42	17.77	23.43	19.54	17.17	17.51	21.23	18.64
M_1	18.90	21.23	22.08	20.74	19.47	21.87	21.27	20.87	19.18	21.55	21.67	20.80
M_2	19.02	20.07	19.85	19.64	19.59	20.67	20.85	20.37	19.30	20.37	20.35	20.01
M_3	18.10	19.25	19.00	18.78	18.50	19.83	21.15	19.83	18.30	19.54	20.07	19.30
SEm (±) S x M	0.13				0.06				0.11			
LSD (p=0.05)	0.38				0.18				0.34			
CV (%)	1.99				0.89				1.72			

Table 7: Interaction effect of the row spacing and mulching on the numbers of plant leaves of the *Kharif* maize crop at harvest

Treatments	**2019**				**2020**				**Pooled**			
Mulching	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**
M_0	18.00	17.34	19.30	18.21	16.47	17.05	23.09	18.87	17.24	17.20	21.20	18.54
M_1	19.15	21.34	20.75	20.41	19.45	21.55	20.96	20.65	19.30	21.45	20.86	20.53
M_2	19.11	20.17	19.82	19.70	19.20	20.37	20.01	19.86	19.16	20.27	19.91	19.78
M_3	18.90	19.00	19.30	19.07	18.00	18.20	20.84	19.01	18.45	18.60	20.07	19.04
SEm (±) S x M	0.05				0.09				0.08			
LSD (p=0.05)	0.15				0.28				0.25			
CV (%)	0.78				1.45				1.29			

Table 8: Impact assessment of the row spacing and mulching on the dry matter (q ha^{-1}) amongst treatment of the *Kharif* maize crop

Treatment	**Plant Dry matter (q ha^{-1})**						**Pooled Plant Dry matter (q ha^{-1})**		
	30 DAS		**60 DAS**		**At Harvest**		**30 DAS**	**60 DAS**	**At Harvest**
	2019	**2020**	**2019**	**2020**	**2019**	**2020**			
Row Spacing									
S_1	11.87	12.08	20.51	21.64	229.68	242.75	11.97	19.93	236.21
S_2	9.06	9.38	15.90	16.38	210.72	216.50	9.38	16.15	213.61
S_3	7.71	7.75	12.88	13.57	180.29	184.74	7.73	13.22	182.51
SEm (±)	0.06	0.05	0.06	0.03	0.58	0.43	0.06	0.03	0.43
LSD (p=0.05)	NS	0.19	0.23	0.14	2.27	1.68	0.23	0.12	1.67
Interaction (R)	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig
Mulching									
M_0	8.88	9.22	15.55	16.22	198.87	207.45	9.05	15.86	203.16
M_1	10.31	10.53	17.97	18.68	218.10	226.69	10.42	18.28	222.39
M_2	9.77	9.79	16.53	17.10	209.91	217.76	9.99	15.36	213.83
M_3	9.22	9.41	15.67	16.78	200.70	206.76	9.32	16.23	203.73
SEm (±)	0.03	0.02	0.02	0.01	0.26	0.30	0.01	0.01	0.33
LSD (p=0.05)	0.08	0.05	0.05	0.03	0.76	0.88	0.04	0.02	0.98
Interaction (M)	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig
Interaction (SxM)	NS	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig
CV%	2.63	1.62	0.94	0.46	0.76	1.24	1.30	0.45	1.41

Table 9: Interaction effect of the row spacing and mulching on the dry matter (q ha^{-1}) of the *Kharif* maize crop at 30 DAS

Treatments	**2020**				**Pooled**			
Mulching	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**
M_0	11.61	9.05	7.00	9.22	11.40	8.85	6.89	9.05
M_1	12.59	9.97	9.02	10.53	12.55	9.83	8.88	10.42
M_2	12.44	9.57	7.35	9.79	12.33	10.04	7.60	9.99
M_3	11.67	8.92	7.65	9.41	11.62	8.79	7.54	9.32
SEm (±) S x M	0.05				0.04			
LSD (p=0.05)	0.16				0.12			
CV (%)	1.62				1.30			

Table 10: Interaction effect of the row spacing and mulching on the dry matter (q ha^{-1}) of the *Kharif* maize crop at 60 DAS

Treatments	2019				2020				Pooled			
Mulching	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**
M_0	19.33	15.43	11.89	15.55	20.58	15.84	12.24	16.22	19.92	15.60	12.07	15.86
M_1	21.47	17.11	15.32	17.97	22.80	17.45	15.78	18.68	22.10	17.20	15.55	18.28
M_2	21.10	16.00	12.48	16.53	21.80	16.64	12.86	17.10	17.00	16.40	12.67	15.36
M_3	20.14	15.05	11.82	15.67	21.35	15.60	13.40	16.78	20.71	15.38	12.61	16.23
SEm (±) S x M	0.05				0.03				0.02			
LSD (p=0.05)	0.15				0.08				0.07			
CV (%)	0.94				0.46				0.45			

Table 11: Interaction effect of the row spacing and mulching on the dry matter (q ha^{-1}) of the *Kharif* maize crop at harvest

Treatments	2019				2020				Pooled			
Mulching	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**	**S_1**	**S_2**	**S_3**	**Mean**
M_0	218.28	206.25	172.07	198.87	231.23	212.44	178.67	207.45	224.76	209.34	175.37	203.16
M_1	246.62	217.10	190.57	218.10	263.93	222.90	193.24	226.69	255.28	220.00	191.91	222.39
M_2	227.39	215.01	187.34	209.91	242.02	220.65	190.59	217.76	234.70	217.83	188.97	213.83
M_3	226.41	204.51	171.17	200.70	233.80	210.02	176.47	206.76	230.11	207.26	173.82	203.73
SEm (±) S x M	0.77				0.89				0.99			
LSD (p=0.05)	2.29				2.64				2.94			
CV (%)	1.12				1.24				1.41			

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