Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2022; 11(3): 193-196
Received: 11-03-2022
Accepted: 17-04-2022

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Effect of row spacing and mulching in the total nutrient uptake of maize (*Zea mays* L.) biomass in the Eastern Uttar Pradesh

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Abstract
Maize is one of the most important cereals crop worldwide and is known as the "queen of cereals". This is because of its very high economic values and also can grow under maximum diverse environments of India as well world. In the light of the above a field experiment was conducted under a split-plot design with three levels of row spacing *i.e.*, S_1, S_2, and S_3 with the 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 find out the effect of row spacing and mulching on the nutrient uptake of maize during two constitutive years (2019, 2020) in eastern Uttar Pradesh. The effect of row spacing and mulching on the nutrient uptake *i.e.*, N, P, K, and S in the maize were observed significant responses during both the year of experimentation. The treatment responses were found significantly better amongst all the treatments of row spacing and it was chronicled in the descending order as $S_2>S_1>S_3$ except sulphur which was in order $S_3>S_2>S_1$. However, with the mulching effect, it was recorded in the descending order as $M_1 > M_2 > M_3 > M_0$ throughout both the years of experimentation. The interaction between row spacing and mulching was significant and was in a similar order to mulching results. The above results row spacing and mulching might be due to the better release of nutrients due to the effect of the treatment.

Keywords: Row spacing, mulching, maize, biomass, and nutrient uptake

Introduction

The maize (*Zea mays* L.) is the world's leading crop and is widely cultivated as cereal grain that was domesticated in Central America. It is one of the most versatile emerging crops having wider adaptability. Globally, maize is known as a queen of cereals because of its highest genetic yield potential. Maize is the only food cereal crop that can be grown in diverse seasons, ecologies, and uses. Beside this maize have many types like normal yellow/ white grain, sweet corn, baby corn, popcorn, waxy corn, high amylase corn, high oil corn, quality protein maize, etc. Apart from this, maize is an important industrial raw material and provides a large opportunity for value addition. Maize contributes maximum among the food cereal crops *i.e.* 40% annually (> 800 mt.) in the global food production. Amongst the maize is growing countries worldwide, India ranks 4th in the area and 7th in the production. This is representing about 4% of the world maize area and 2% of total production. Regarding the area and production of maize, during 2018-19 in India, the maize area has reached 9.2 million ha. The production of maize was during 1950-51 in India used to produce 1.73 million MT maize, which had been enlarged to 27.8 million MT by the year 2018-19, recording close to 16 times increase in the production (maize outlook report, January to May 2021, Agricultural Market Intelligence Centre, ANGRAU, Lam May 2021) [1]. 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) [2].

Maize is cold-intolerant, in the temperate zone maize must be planted in the spring. Its root system is generally shallow, so the plant is dependent on soil moisture. As a plant that uses C_4 carbon fixation, maize is a considerably more water-efficient crop than plants that use C_3 carbon fixation such as alfalfa and soybeans. Maize is most sensitive to drought at the time of silk emergence when the flowers are ready for pollination. In the United States, a good harvest was traditionally predicted if the maize was "knee-high by the Fourth of July", although modern hybrids generally exceed this growth rate. Maize used for silage is harvested while the plant is green and the fruit immature.

Farmers can readily vary maize plant density along with the landscape positions of the fields using current technology and historical field variability information. Row spacing, on the other hand, is more difficult to change.

As a result, using the same row spacing for a field's various landscape sites may reduce maize grain output. Two tests were done in the Inland Pampas of Argentina to test this theory in fields with varying landscape positions.

Materials and Methods

The study was carried out at the Agricultural Research Farm of the S.D.J.P.G. College, Chandeswar, and Azamgarh, Uttar Pradesh (India) during *kharif* seasons of the 2019 and 2020, (Table 1). 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 the 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 1140 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 4 m X 4 m for experimentation 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 and yield parameters. 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 critical difference (LSD) at a 5% level of probability (Gomez and Gomez, 1976) [12]. Standard procedures were adopted for recording the data of agronomic growth-related parameters.

Table 1: Schedule of field operations

S. No.	Operation	Year 2019	Year 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 1. Hand weeding 2. Hand weeding	10.08.2019 02.09.2019	15.08.2020 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 Discussions

Nutrient uptake by biomass (kg ha^{-1}) of the maize

The data pertaining to N, P, K, and S uptake by biomass of the maize crop were significantly enhanced by the influence of the row spacing and mulching treatments during both years (Table 2). The data in the year 2020 was found a greater response than in the year 2019 with all the treatments of the row spacing and mulching and the pooled data also showed the N, P, K, and S uptake, similarly.

The treatment effects of the row spacing were chronicled in the descending order as $S_2>S_3>S_1$ for nitrogen uptake during both the years of the experiment and pooled data also reflected similarly. The uptake of phosphorus by the maze was recorded in the descending order of $S_2>S_3>S_1$ in the year 2019 but it was for the year of 2020 as $S_3>S_2>S_1$ and pooled data was found in the order of $S_2>S_3>S_1$ and the similar trend was noticed in the uptake of potassium *i.e.* $S_2>S_3>S_1$ during both the year of experimentation. The effect of row spacing for the uptake of sulphur was noted in the decreasing order as $S_3>S_2>S_1$ during both the years of the experimentation as well pooled analysis of data also depicted the similar consequences.

The uptake of nitrogen during both the years of experiment and pooled data was also reflected as $S_2>S_3>S_1$. The uptake of phosphorus by the maze was recorded in the descending order of $S_2>S_3>S_1$ in the year 2019 but it was for the year of 2020 as $S_3>S_2>S_1$ and pooled data was found in the order of $S_2>S_3>S_1$ and the similar trend was noticed in the uptake of potassium *i.e.* $S_2>S_3>S_1$ during both the year of experimentation. The effect of row spacing for the uptake of sulphur was noted in the decreasing order as $S_3>S_2>S_1$ during both the years of the experimentation as well pooled analysis of data also depicted the similar consequences.

The different mulching effects in the maize biomass of the N, P, K, and S uptake were chronicled in the descending order as $M_1=M_2>M_3=M_0$. It means the treatment M_1 and M_2 are equivalent among themself and similar results also obtained between M_3 and M_0. Nevertheless, the treatment effect was significantly higher $M_1=M_2$ in the uptake of maize biomass than the treatment effect of M_3 and M_0. Amongst the mulching treatments recorded significantly the highest biomass N uptake than the control (no mulch). Data further revealed that amongst mulching treatments, significantly the highest N uptake by biomass of maize was recorded under M_1-paddy straw mulch treatment as compared to M_2-green weed mulch, M_3-dust mulch, and M_0-control (No mulch), respectively during both the years. The increase in the content of nutrients by crop might be due to the fact that the soil covered by mulching and affects to restores the moisture and provide a better environment for the availability of nutrients to increase crop growth, nutrient influx, and which resulted in more absorption and translocation of these nutrients to the grain and stover and total increase the N, P, K, and S uptake in the maize of biomass and almost similar results are reported by the Rina and Singh *et al*., 2020 [4]; Dutta *et al*., 2015 [5]; Bharud *et al*., 2014 [6]; Naik *et al*., 2012 [7]; Enujeke *et al*., 2013 [8].

The interaction effect of row spacing and mulching practices by the maize biomass of the uptake of nitrogen in the year 2019 was recorded in the sequence as S_1M_2, S_2M_2, and S_3M_1, and its mean value was at par between M_1 with M_2. But in the year 2020, it was significantly superior amongst themselves and was in order S_1M_1, S_2M_2, S_3M_1, and pooled data also reflected similarly. In case P, K, and S uptake were chronicled as S_1M_1, S_2M_1, S_3M_1, and pooled data significantly higher amongst themselves and the rest of the treatments were chronicled significantly highest P, K, and S uptake by biomass along with the application of M_1-paddy straw mulch treatment over other treatment combinations during both the years of the experiment (Table 3, 4, 5, and 6). Sanders *et al.* (2017) [9] The area dedicated to corn (*Zea mays* L.) production increased 50% in the south eastern United States between 2006 and 2016 and utilized a perennial legume in a living mulch system helped stabilize corn shaded when shading increased that enhanced the total biomass of the maize due to effect of shading increased that resulted by optimized potentially mineralizable nitrogen. Dobbratz *et al.* (2019) [10] experimented with Kura clover grass which is a perennial living mulch with three-row preparation strategies that have been commonly used in living mulch systems and produced 4.0 Mg ha^{-1} more grain and 3.5 Mg ha^{-1} more stover biomass because of management of the soil health, soil moisture & temperature, corn (*Zea mays* L.) emergence, corn development, and corn yield.

Sidhu *et al.* (2007) [11] experimented on the maize crop for four years (1999 - 2002) to study the effect of wheat straw mulch (0 and 6 t ha^{-1}) and planting methods (flat and channel) and reported that due to mulching effects produced biomass yield by 1.57 t ha^{-1}.

Table 2: Effect of row spacing and mulching on N, P, K, and S Uptake in biomass of the *kharif* sessions maize crop (kg ha^{-1})

Treatment	Nitrogen			Phosphorus			Potassium			Sulphur		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
Row Spacing												
S_1	277.82	294.02	285.92	45.91	50.80	48.35	155.66	172.70	164.18	37.17	41.60	39.38
S_2	317.80	329.50	323.65	58.18	68.58	63.38	197.34	230.50	213.92	60.23	70.39	65.31
S_3	262.69	284.79	273.74	57.47	68.94	63.21	186.98	221.94	204.46	70.17	83.22	76.69
S.Em (±)	0.37	0.39	0.38	0.06	0.07	0.07	0.22	0.25	0.23	0.06	0.07	0.06
CD (p=0.05)	1.47	1.55	1.51	0.25	0.29	0.27	0.87	0.98	0.92	0.24	0.27	0.25
Interaction (R)	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG
Mulching												
M_0	258.73	272.21	265.47	47.53	55.85	51.69	153.45	180.13	166.79	41.60	49.38	45.49
M_1	313.53	334.22	323.87	61.15	70.90	66.03	209.74	238.95	224.35	72.26	82.85	77.55
M_2	313.17	322.25	317.71	58.28	67.49	62.88	194.31	223.55	208.93	62.10	71.84	66.97
M_3	258.98	282.40	270.69	48.46	56.86	52.66	162.48	190.88	176.68	47.47	56.20	51.84
S.Em (±)	0.30	0.32	0.31	0.06	0.07	0.06	0.19	0.22	0.20	0.05	0.06	0.06
LSD (p=0.05)	0.90	0.96	0.93	0.17	0.20	0.18	0.55	0.65	0.60	0.16	0.19	0.18
Interaction (M)	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG
Interaction (SxM)	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG	SIG
CV %	0.96	0.96	0.96	0.94	0.95	0.94	0.93	0.94	0.94	0.89	0.90	0.89

Table 3: Interaction effect of the row spacing and mulching in the nitrogen uptake (kg ha^{-1}) in the biomass of *Kharif* maize

Treatments	2019				2020				Pooled			
Row Spacing / Mulching	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
M_0	260.67	287.06	228.46	258.73	269.92	315.20	231.52	272.21	265.29	301.13	229.99	265.47
M_1	283.83	345.43	311.33	313.53	319.07	350.81	332.76	334.22	301.45	348.12	322.04	323.87
M_2	303.21	353.62	282.67	313.17	306.77	358.69	301.29	322.25	304.99	356.16	291.98	317.71
M_3	263.56	285.08	228.29	258.98	280.31	293.31	273.60	282.40	271.93	289.20	250.94	270.69
S.Em (±) S x M	0.91				0.97				0.94			
LSD (p=0.05)	2.71				2.87				2.79			
CV (%)	0.96				0.96				0.96			

Table 4: Interaction effect of the row spacing and mulching in the phosphorus uptake (kg ha^{-1}) in the biomass of *Kharif* maize

Treatments	2019				2020				Pooled			
Row Spacing / Mulching	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
M_0	38.81	52.86	50.91	47.53	42.83	63.99	60.74	55.85	40.82	58.43	55.83	51.69
M_1	51.98	63.51	67.98	61.15	57.60	73.94	81.15	70.90	54.79	68.73	74.56	66.03
M_2	50.19	62.83	61.82	58.28	55.31	73.05	74.10	67.49	52.75	67.94	67.96	62.88
M_3	42.67	53.53	49.18	48.46	47.45	63.33	59.79	56.86	45.06	58.43	54.48	52.66
S.Em (±) S x M	0.17				0.20				0.18			
LSD (p=0.05)	0.50				0.59				0.55			
CV (%)	0.94				0.95				0.94			

Table 5: Interaction effect of the row spacing and mulching in the potassium uptake (kg ha^{-1}) in the biomass of *Kharif* maize

Treatments	2019				2020				Pooled			
Row Spacing / Mulching	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
M_0	135.39	162.58	162.38	153.45	149.82	196.81	193.74	180.13	142.61	179.70	178.06	166.79
M_1	179.38	238.15	211.70	209.74	199.36	269.80	247.70	238.95	189.37	253.97	229.70	224.35
M_2	165.33	217.15	200.44	194.31	182.71	252.47	235.46	223.55	174.02	234.81	217.95	208.93
M_3	142.53	171.49	173.41	162.48	158.91	202.90	210.84	190.88	150.72	187.19	192.13	176.68
S.Em (±) S x M	0.56				0.66				0.61			
LSD (p=0.05)	1.65				1.95				1.80			
CV (%)	0.93				0.94				0.94			

Table 6: Interaction effect of the row spacing and mulching in the sulphur uptake (kg ha-1) in the biomass of *Kharif* maize

Treatments	2019				2020				Pooled			
Row Spacing / Mulching	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
M_0	23.47	39.90	61.44	41.60	26.19	48.30	73.66	49.38	24.83	44.10	67.55	45.49
M_1	50.96	79.38	86.43	72.26	57.13	90.67	100.74	82.85	54.04	85.03	93.59	77.55
M_2	44.28	66.14	75.87	62.10	49.38	76.89	89.24	71.84	46.83	71.52	82.56	66.97
M_3	29.96	55.51	56.94	47.47	33.70	65.68	69.23	56.20	31.83	60.59	63.09	51.84
SEm (±) S x M	0.16				0.19				0.18			
LSD (p=0.05)	0.49				0.58				0.53			
CV (%)	0.89				0.90				0.89			

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