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Effect of nitrogen and sulphur levels on growth and yield of maize (*Zea mays* L.)

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Abstract
A field experiment was conducted during *Zaid* season of 2020 at experimental field of the Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology & Sciences, Prayagraj, and Uttar Pradesh, India to determine the soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 6.7), medium in organic carbon (0.72%), available nitrogen (114.8kg/ha), available phosphorus (17.14 kg/ha), available potassium (156.2 kg/ha), The effect of nitrogen and sulphur levels growth and yield of maize (*Zea mays* L.). ten treatments consisted of three levels of nitrogen (100, 120 and 140 kg/ha) and three levels of sulphur (30, 45, 60 kg/ha) replicated thrice in along with control. The experiment was carried out through a statistical design of Randomized Block Design (RBD). The result showed that growth parameters *viz.* plant height (234.46 cm), at 80 DAS number of leaves/plant (13.40), Dry weight (100.82 g/plant), and Crop growth Rate (2.97 g m^{-2}/day), at 60-80 DAS Relative Crop Growth Rate (0.043 g/g/day) at 60-80- DAS and yield parameters *viz.*, test weight (281.4 g), cob/plant (1.50 $plant^{-1}$), No. of grains/cob (425.93), Grain's yield (8.33 t/ha) and stover yield (16.28 t/ha) were observed 140 kg/ha nitrogen and 60 Kg/ha sulphur.

Keywords: Hybrid maize, nitrogen levels, sulphur levels, yield parameters

Introduction
Maize (*Zea mays* L.) is the third most important food grain in India after the main cereals rice and wheat. India ranks fifth in area and third in production and productivity of maize in the line of cereal crops and members of Gramineae family and it is one of the most important cereal crops quoted as the 'Queen of Cereals'. Besides, human consumption and for animal feed maize can also be used in certain industries like corn starch industries, corn oil production, corn flakes industries etc. The global consumption pattern of maize is: feed-61%, food-17% and industry-22%. It has attained a position of industrial crop globally as 83% of its production in the world is used in feed, starch and bio fuel industries. Further, using maize directly or indirectly more than 3000 products are being made providing wide opportunity for value addition. Because of its myriad uses, it is a prime driver of the global agricultural economy.

Among the maize growing countries India rank 4th in area and 7th in production, representing around 4% of world maize area and 2% of total production. During 2018-19 in India, the maize area has reached to 9.2 million/ha. During 1950-51 India used to produce 1.73 million MT maize, which has increased to 27.8 million MT by 2018-19, recording close to 16 times increase in production. The average productivity during the period has increased by 5.42 times from 547 kg/ha to 2965 kg/ha, while area increased nearly by three times. (Ali, 2013) [1] Though the productivity in India is almost half of world the average per day productivity of Indian maize is at par with many leads maize's producing countries.

Effective supply of nitrogen through inorganic and organic sources may increase the production of maize as well as improve the quality of food grains and soil environment. (Agustin, 2012) [2].

Crop responses to organic and biological nutrient carriers are not as spectacular as fertilizer but the supplementary and complementary use of such sources is known to enhance the utilization efficiency of fertilizer. The low fertility status of most tropical soils hindered maize production as maize has a strong exhausting effect on the soil. (Azeem, 2014) [3].

Macro and micro nutrients play very important role for maize production due to nutrient deficiency causes average loss in yield. (Channabasamma, 2013) [6] Proper dose and management of fertilizers help to increase growth and yield of plant. (Dostalova, 2015) [8] Nitrogen is very important and major part contributing nutrient which associated with

photosynthetic activities while in excess it can delay crop maturity. (H. Klikocka, 2016) [12] Scarcity of nitrogen leads to slow down of photosynthesis which hampers source to sink relationship and translocation of photosynthesis. (Kumar, 2016) [4] Nitrogen management in agronomic practices need more concentration for better crop establishment and yield point of view. (Humtsoe, 2018) [11] Sulphur concentration usually range in 0.2-0.5 percent in vegetative tissues. (Singh, 2014) [17] Sulphur is helpful in synthesis and accumulation of sulphur containing amino acids (cystein, cysteine and methionine), chlorophyll and proteins. (Dai, 2015) [9] suggested that, sulphur is mainly responsible for availability and supply of nitrogen, hence, with increasing dose of sulphur the availability and uptake of nitrogen is increased. (Sean, 2014) [18] this study aimed to study the effect of Nitrogen and Sulphur levels on growth and yield of maize and to work out the Economic of different treatment combination. (Peter, 2012) [16] Sulphur is one of the essential nutrients for plant growth. plants require S in amounts similar to phosphorus. (Binod Kumar, 2016) [14] Sulphur has specific functions during plant growth, metabolism, and enzymatic reactions (Bhagyalaxmi, 2010) [5], it is required for the synthesis of sulphur-containing amino acids such as cystine, cysteine, and methionine. A deficiency of Sulphur causes plants to be uniformly chlorotic, stunted, thin stemmed, and spindly, growth is retarded and consequently, yield is reduced. (Daoudi, 2017) and (Jena, 2015) [10, 13]. Keeping in view the above facts the present investigation was conducted to study the response of maize crop under different levels of nitrogen and sulphur treatment at Prayagraj condition. Sulphur is one of the 16 elements essential for crop production. Sulphur is considered as the fourth major nutrient element for crops. (Muhammad, 2017) [15] It is typically considered a secondary macronutrient (along with calcium and magnesium), but is essential for maximum crop yield and quality. (Shrinivasrao, 2010) [19] Sulphur is often ranked immediately behind nitrogen, phosphorus and potassium in terms of importance to crop productivity. (Vijaya, 2018) [20] Sulphur is a component of the amino acids cysteine, cystine and methionine. making it essential for protein synthesis in plants. Plants also contain a large variety of other organic sulphur compounds such as glutathione. (Dawadi, 2012) [7] Sulphur is also a constituent of vitamins (thiamine and biotin), glycosides and co-enzyme.

Materials and Methods

A field experiment was conducted to study the Nitrogen and Sulphur levels on growth and yield of Maize [*Zea mays L.*]" during *Zaid* season of 2020 at the Crop Research Farm, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj which is located at geographical coordinates 25° 24' 42" N latitude, 81° 50' 56" E longitude and 98 m altitude above the mean sea level. The experimental soil contained 0.72% medium organic carbon, 114.8 kg/ha low nitrogen, 17.14 kg/ha available medium phosphorus and potassium with pH 7.4. The treatment consisted of three levels of Nitrogen (100,120,140) and Sulphur (30, 45 and 60 kg/ha) along with control There were ten treatments which replicated thrice. The experiment was laid out in Randomized Block Design. In all the treatments nitrogen and sulphur was applied accordingly basal doses factor as basal dose and entire dose of phosphorous, potassium commonly applied. The growth parameters *viz.*,plant height, no. of leaves and dry weight (g/plant) also yield parameters *viz.*, no. of cob/plant, no. of grain/cob, grain yield (t/ha), stover yield (t/ha), with standard process & observation were recorded data was statistically analyzed, analysis & variance (ANOVA) as applicable to Randomized Block Design (Gomez and Gomez., 1984)

Result and Discussion

Growth Parameters

Data pertaining to growth parameters were recorded and depicted in table 1. Significantly Maximum plant height (234.46 cm) was recorded at harvest with treatment T_9 140 kg N/ha and 60 kg S/ha whereas, treatment 100 kg/ha N and 60 kg/ha S and T5 120 kg/ha N and 45 kg/ha S, T6 120 kg/ha N and 60 kg/ha S, T7 140 kg/ha N and 30 kg/ha S, and T8 140 kg/ha N and 45 kg/ha S was found statistically at par with treatment T9 140 kg N/ha and 60 kg S/ha. Significantly maximum no. of leaves (13.40/plant) and dry weight (100.82) per plant was also observed with treatment T9 140 kg N/ha and 60 kg S/ha which was closely followed by treatment T6 120 kg/ha N and 60 kg/ha S in both observations.

Increase in plant height, no. of leaves and dry weight per plant with to increase in nitrogen and sulphur application is ascribed to its positive effect on plants. The probable reason for attaining maximum values & afonssoid parameters with nitrogen as sulphur application. This finding is in accordance by Souza *et al.* (2017). and Pavithra *et al.* (2018) Higher photosynthetic activity and chlorophyll synthesis due to nitrogen and sulphur fertilizers seemed to give a favourable effect on plant height, no. of leaves and dry weight.

Number of leaves per plant

The average number of leaves per plant markedly increase due to nitrogen application at all the growth stages. Application of 140 kg N/ha and 60 kg S/ha produced maximum number of leaves (13.40/plant) at 80 days after sowing during the crop cycle. Similar results have been reported by Souza *et al.* (2017). Further, nitrogen might have increased the chlorophyll content of leaves and resulted in increased synthesis of carbohydrates, which led to new cells formation and thus increased the number of leaves. It was observed that the higher number of leaves by higher number of nitrogenous fertilizers significantly affected the number of leaves per plant.

Table 1: Effect of Nitrogen and Sulphur levels on growth atrtributes of Maize (*Zea mays* L.)

At harvest (80 DAS)						
Treatment	**Treatment combinations**	**Plant height (cm)**	**No. of leaves/plant**	**Dry weight (g/plant)**	**CGR (g/m^2/day)**	**RGR (g/g/day)**
T_1	100 Kg/ha N + 30 kg/ha S	210.58	12.67	76.32	2.023	0.23
T_2	100 Kg/ha N + 45 kg/ha S	217.86	12.73	75.30	2.142	0.026
T_3	100 Kg/ha N + 60 kg/ha S	229.59	12.87	80.82	2.457	0.026
T_4	120 Kg/ha N +30 kg/ha S	211.25	12.60	70.81	2.159	0.026
T_5	120 Kg/ha N + 45 kg/ha S	230.57	12.60	71.00	2.296	0.025
T_6	120 Kg/ha N + 60 kg/ha S	232.62	13.00	90.80	2.607	0.032
T_7	140 kg/ha N + 30 kg/ha S	225.38	12.40	80.80	2.187	0.024

T_8	140 kg/ha N + 45 kg/ha S	224.89	12.82	75.60	2.382	0.024
T_9	140 kg/ha N + 60 kg/ha S	234.46	13.40	100.82	2.976	0.043
T_{10}	N-P-K/ha 120:60:60 (control)	200.10	12.20	60.82	1.902	0.023
	S.Ed(+)	6.341	0.270	7.971	0.473	0.007
	CD (P=0.05)	13.321	0.567	16.747	-	-

Table 2: Effect of Nitrogen and Sulphur levels on yield and yield attributes of Maize (*Zea mays* L.)

Treatment	Treatment combinations	At harvest Yield and yield attributes						
		No. of cob/plant	Cob length (cm)	Cob weight (g)	No. of grains /cob	Grains yield (t/ha)	Stover yield (t/ha)	Test weight (g)
T_1	100 Kg/ha N + 30 kg/ha S	1.02	21.93	172.80	315.67	6.80	14.96	278.1
T_2	100 Kg/ha N + 45 kg/ha S	1.03	20.07	151.80	328.07	7.20	13.32	279.7
T_3	100 Kg/ha N + 60 kg/ha S	1.04	22.07	208.53	357.32	7.03	15.28	279.1
T_4	120 Kg/ha N +30 kg/ha S	1.30	20.14	159.80	322.82	7.30	13.08	280.1
T_5	120 Kg/ha N + 45 kg/ha S	1.30	20.47	174.82	320.32	6.73	13.96	277.5
T_6	120 Kg/ha N + 60 kg/ha S	1.10	22.13	218.87	394.23	8.17	15.68	281.2
T_7	140 kg/ha N + 30 kg/ha S	1.03	21.47	171.80	381.80	7.00	13.96	278.6
T_8	140 kg/ha N + 45 kg/ha S	1.20	21.40	174.47	314.80	7.83	13.98	280.3
T_9	140 kg/ha N + 60 kg/ha S	1.50	22.33	223.60	425.93	8.33	16.28	281.4
T_{10}	N-P-K/ha120:60:60 (control)	1.00	20.13	140.67	312.00	4.60	11.66	277.1
	S.Ed(+)	0.007	0.840	5.791	29.091	0.673	1.505	0.54
	CD (P=0.05)	0.016	1.765	12.166	61.118	1.414	3.162	1.14

Yield attributes

Data related to yield attributes was recorded at harvest and presented in table 2. Maximum of number of cob/plants was recorded significantly superior with treatment T9 application of 140 kg/ha N and 60 kg/ha S. significantly higher cob length (cm) cob weight (g) and no. of grains/cob were also recorded with treatment T9 (140 kg/ha N and 60 kg/ha S), while in case of cob length (cm) T1, T3, T6, T7 and T8 found at par. Whereas, in cob weight (g) treatment T6 and in case of no. of grain /cob treatment T6 and T7 were noticed to be on par with T9 (140 kg/ha N and 60 kg/ha S)

1000 seed weight (g) was recorded significantly maximum with treatment T9 (140 kg/ha N and 60 kg/ha S) except treatment T6 (120 kg/ha N and 60 kg/ha S) was followed similar then as.

In maize, yield of crop is the manifestation of yield attributes characters. Higher grain yield could be attributed to higher yield attributing character like no. of cob/plant and stover yield (16.28), grain weight/cob, no. of grain/cob, significantly maximum grain yield (8.33 t/ha) was recorded with treatment T9 (140 kg/ha N and 60 kg/ha S). whereas, T2, T3, T6, T7 and T8 was found to be at par with maximum yield producing treatment T9 (140 kg/ha N and 60 kg/ha S).

The improvement in grain yield and stover yield under increasing nitrogen levels and sulphur levels also due to accelerated plant height, number of leaves and dry weight. Nitrogen and sulphur help to better photosynthesis and considerably increased dry weight of plant

Moreover, nitrogen and sulphur nutrients have synergistic effect on growth and yield attributes resulting in greater translocation of photosynthesis from source to sink help to maximize maize yield. These finding is accordance Amjed *et al.* (2013).

Heavy feeding of crop plant with higher dose of nitrogen to lead for greater yield attributes. Highest nitrogen dose and sulphur might have promoted the intermodal elongation, succulence and shoot growth have promoted photosynthetic activity and improve yield attributes accordingly Pavithra *et al.* (2011) and Murad Ali (2016). Also, same result.

Yield attributes of Maize *viz.* no. cobs/plant, cob length(cm), cob weight (g) no. of grains/cob, Test weight(g) were significant among different treatments. The T9 Nitrogen 140 kg/ha and Sulphur 60 kg/ha shows significantly higher in among the treatment as compared to other. The T9 has highest result in cobs/plant (1.50), cob length (22.33cm), cob weight (223.60 g), no. of grain/cob (425.93), test weight (281.4). In cobs plant^{-1} significantly, in cob length T1, T6, T7 and T8 is at par to T9, cob weight (g) T6 is at par to T9, in no. of grains/cob T6and T7 is at par to T9, Test weight (g) T6 is at par to T9. While the lowest data was record in T10 control as shown in table no.3

Number of cobs per plant

Yield attributing character like number of cobs per plant, the results revealed that there was significant difference between the treatments and maximum number of cob/plant (1.50/plant^{-}) was observed by the application of T_9 140 Kg N/ha + 60 kg S/ha. The data regarding the number of cobs per plant are presented in table 3, which indicated that application of nitrogen and Sulphur partly affected the number of cobs per plant. It seems that number of cobs per plant is basically a genetic character and not too much influenced by crop nutrition. These results are in line with the finding of Amjed *et al.* (2013).

Cob length

This result was in accordance with the data recorded by Pavithra *et al.* (2011). That the significant increase in yield parameters was due to application of higher doses of N and S fertilizers which enhanced nutrients uptake by the crop, by better translocation of photosynthates from source to sink. Grain and stover yield is also higher due to higher growth and yield parameters like cob length etc.

Cob weight

Maximum Cob weight (223.60g) was observed by the application of T_9 140 Kg N/ha + 60 kg S/ha, this result was in accordance with the data recorded by Pavithra *et al.* (2011). Higher rate of nitrogen and sulphur had beneficial effect on physiological processes, plant metabolism, dry matter production, growth, cob length, cob weight etc.

Number of grains per cob

The results revealed that there was significant difference between the treatments and maximum No. of grains/cob (312.00) was observed by the application of T_9 140 Kg N/ha + 60 kg S/ha and T_6 120 Kg N/ha + 60 kg S/ha and T_7 140 kg N/ha + 30 kg S/ha were found to be statistically at par T_9

The number of grains per cob was increased at 150 kg N ha^{-1} as compared to 0 kg N/ha (control) similarly seed priming improved grains/cob Many researchers have founded increase in grains per pod in case of legumes or number of grains per cob in case of corn. Interactive effect of seed priming and nitrogen levels. results of water soaked and P priming were highly increased as compared to control but the high yield of grains per cob was showed by high nitrogen levels. the increasing the levels of N increase the number of grains/cobs. This result was in accordance with the data recorded by Murad Ali (2016).

Yield

Yield of Maize viz. grain yield(t/ha), stover yield(t/ha), were found to be significant in among the treatment. The T9 Nitrogen 140 kg/ha Sulphur 60 kg/ha shows significantly higher in among the treatment. It shows significantly higher in grain yield (8.33 t/ha), stover yield (16.28 t/ha), In grain yield T6, T3, T4, T2, T7 and T8, is at par to T9, in stover yield T8, T6, T5, T1, T2, T3, T7 is at par to T9, While the lowest data was record in T10 control as shown in table no.3

Grain yield

Maximum grain yield (8.33 t/ha) was recorded due to application of 140 kg N/ha and 60 kg S/ha at 80 DAS which was proved significantly superior over the application of 100 and 120 kg N/ha and 30, 45 kg S/ha. This result was in accordance with the data recorded by Pavithra *et al.* (2011). Higher rate of nitrogen and sulphur had beneficial effect on physiological processes, plant metabolism, dry matter production, growth etc. there by leading to higher grain yield.

Stover yield

The results revealed that there was significant difference between the treatments and maximum stover yield (16.28 t/ha) was observed by the application of T_9 140 Kg N/ha + 60 kg S/ha, and T_1 100 Kg N/ha + 30 kg S/ha, T_2 100 Kg N/ha + 45 kg S/ha, T_3 100 Kg N/ha + 60 kg S/ha, T_5 120 Kg N/ha + 45 kg S/ha, T_6 120 Kg N/ha + 60 kg S/ha, T_7 140 kg N/ha + 30 kg S/ha and T_8 140 kg N/ha + 45 kg S/ha were found to be statistically at par T_9 Maximum strover yield (16.28 t/ha) was recorded due to application of 140 kg N/ha and 60 kg S/ha at 80 DAS which was proved significantly superior over the application of 100 and 120 kg N/ha and 30, 45 kg S/ha. This result was in accordance with the data recorded by Pavithra *et al.* (2011). Higher rate of nitrogen and sulphur had beneficial effect on physiological processes, plant metabolism, dry matter production, growth etc. there by leading to higher stover yield.

Conclusion

At the above research, it may be concluded that in Maize crop the application of Nitrogen 140 kg/ha and Sulphur 60 kg/ha is the best combination for obtaining better growth attributes like plant height, no. of leaves/plant, dry weight and higher yield attributes of hybrid maize like no. of cob/plant, cob length (cm), cob weight(g), no. of grain/cob, Test weight (g), grain yield (t/ha), stover yield (t/ha), and can be recommended to the farmers of Allahabad region for sustaining productivity and profitability of maize

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