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

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Abstract
A field experiment entitled "Effect of nitrogen and Sulphur levels on growth, yield and quality of maize (*Zea mays* L.)" was conducted at the Instructional Farm, Department of Agronomy, AKS University, Satna (M.P.) during the *kharif* season of 2019-20. A set of 12 treatment combinations including four nitrogen levels *viz*., 0 kg/ha (N_0), 80 kg/ha (N_1), 100 kg/ha (N_2) and 120 kg/ha (N_3) with three Sulphur levels *viz*., 20 kg/ha (S_1), 30 kg/ha (S_2) and 40 kg/ha (S_3) were evaluated. Treatments were replicated thrice as per Randomized Block design with Factorial concept. Crop sown with application of nitrogen @ 120 kg/ha combined application with Sulphur @ 40 kg/ha attained significantly higher plant growth and yield at all the growth stages of plant. The significantly higher plant height, number of leaves per plant, number of rows per cob, number of grains per cob, length of cob, grain and stalk yield per hectare and protein content of maize at maximum crop growth stage was recorded under the application of nitrogen @ 120 kg/ha combined application with Sulphur @ 40 kg/ha with the respective values of 213.88 cm, 13.53, 15.87, 316.93, 15.28 cm, 52.03 q/ha, 63.68 q/ha and 11.85%, respectively proved significantly superior to rest of the treatments. Result showed that maize variety when sown the application of nitrogen @ 120 kg/ha combined application with Sulphur @ 40 kg/ha recorded the maximum and significantly higher values of these parameters.

Keywords: Maize, Sulphur, growth stage, cobs, stalk yield

1. Introduction
Maize (*Zea mays* L.) also called corn, is one of the most crucial and strategic crops in the world. Corn means literally "that which sustains life". Maize is emerging as an important world cereal crop after wheat and rice, which is "Queen of Cereals", due to the high productiveness, easy to process, low cost than other cereals (Jaliya *et al*., 2008) [9], provides nutrients for humans and animals, serves as basic raw materials for production of starch, oil, protein, alcoholic beverages, food sweetness and more recently fuel.
The nutritional composition of maize (per 100 g) is as follows protein 4 g, 30 g carbohydrate, 3.5 g dietary fiber, 1.5 g fat, 3.6 g sugar, 310 iu vit A, 4 mg calcium, 0.72 mg zinc etc. fwww.seedgufdes.info/maize L. It has an important role in the industry as more than 35 products of daily use are derived from maize. It is raw material for a number of products via. Starch, lactic acid, glucose, acetic acid, dextrose, sorbitol, dextrin, high fructose syrup, maltodextrin, germ oil, germ application in industries such as alcohol, textile, paper, pharmaceutical, organ chemical, cosmetics and edible oil.
In India, maize is cultivated on 9.23 million hectare area with a production of 23.67 million tonnes and productivity of 2.56 t/ha during the year 2014- 15 (Anonymous, 2015) [1]. In Madhya Pradesh it covers an area of 1098 thousand ha with a production of 2580.3 thousand tones at an average productivity of 2350 kg/ha. Area covered under maize crop in Satna district of 800 ha, production of 700 tonnes with productivity of 886 kg/ha (Anonymous, 2015-16) [3].
It is well known that maize is a heavy feeder crop and it well responded to fertilization, especially where soils are generally low in native fertility. It is generally observed that maize fails to produce worthwhile grain yield in plots without fertilizer application. Soil fertility is a major constraint to it productivity, low organic matter content coupled with low and imbalance application of nutrients limits its full potential yield and is the main yield barrier. Nitrogen is universally deficient in majority of Indian soil and experiment conducted at various places in different agroclimatic zones of India indicated that nitrogen has beneficial effect on growth, yield attributing characters and yield of maize. Most of the varieties of maize are single cross

hybrids in which nitrogen stress before flowering reduces leaf area and photosynthesis.

Nitrogen stress during flowering stage results in kernel and ear abortion, whereas stress during grain filling accelerates leaf sencence, reduces photosynthesis and kernel weight. Thus, for enhancing grain yield of single cross hybrids of maize, nitrogen fertilization has emerged as a serious matter of concern for maize growing farmers.

Sulphur is very essential for many growth functions of the plant like nitrogen metabolism, enzyme activity, protein and oil synthesis. Sulphur is necessary to achieve maximum efficiency of applied nitrogen fertilizer. Combined effect of nitrogen and Sulphur has the largest effect on the concentration and uptake of nutrients by the maize plant and on protein content of the seed. Sulphur is one of the essential nutrients for plant growth. Plants require Sulphur in amounts similar to phosphorus. Sulphur has specific functions in plant growth, metabolism and enzymatic reactions. Sulphur is also required for the synthesis of Sulphur containing amino acids such as cystine, cysteine, and methionine. Sulphur is also a constituent of S-glycosides (mustard oils), coenzyme-A and vitamins (biotin and thiamine) (Tisdale *et al*., 1985) [21]. As maize is more exhausting in its demand for growth promoting factors, it is very crucial to determine the optimum rate of nitrogen fertilizer application as exceeding dosage may result in crop lodging, delayed silking, enhanced number of barren ears, poor grain quality and subsequently, lower grain productivity.

The interaction of these nutrient elements may affect the critical levels of available nitrogen and Sulphur below which response to their application could be observed. Information on effect of combined application of nitrogen and Sulphur on growth, yield, and quality of each nutrient in maize is rather limited in the sub-tropical zone of M.P. Keeping these points in view, the present investigations were under taken.

Materials and Methods

The experiment was carried out at the Instructional Farm, department of Agronomy, AKS University, Satna (M.P.) during the *kharif* season of 2019-20. The experiment was conducted in randomize complete block design having Factorial concept with three replications. Different rates of nitrogen and Sulphur allocated to the plots as per treatments. The treatments were four levels of nitrogen levels *viz*., 0 kg/ha (N_0), 80 kg/ha (N_1), 100 kg/ha (N_2) and 120 kg/ha (N_3) with three Sulphur levels *viz.*, 20 kg/ha (S_1), 30 kg/ha (S_2) and 40 kg/ha (S_3). The gross and net plot size was 5.0 m x 3.5 m and 4.0 m x 3.0 m, respectively. The fertilizers grades were applied as per treatments. The recommended dose of phosphorus and potassium was applied @ 60 kg P_2O_5/ ha and 40 kg K_2O/ ha respectively while, nitrogen (N) and Sulphur (S) was applied as per the treatments. All the other agronomic practices were applied uniformly to all the treatments.

Results and Discussion

The result shows that plant height, number of leaves per plant, number of rows per cob, number of grains per cob, length of cob, grain, stalk yield per hectare and protein content percent was influenced significantly due to different concentrations of nitrogen and Sulphur.

Data present in (Table- 1 & Table -2) maximum plant height and number of leaves per plant (206.15 cm and 13.16, respectively) were recorded in plots treated with the application of nitrogen @ 120 kg/ha (N_3) while, lowest values were observed in plot that received no nitrogen. Similarly, application of Sulphur @ 40 kg/ha gave maximum plant height and number of leaves per plant with the respective of 194.12 cm and 12.72, respectively.

Data revealed that interaction effect of nitrogen and Sulphur significantly affected plant growth was found significant. Similarly, in interaction the maximum plant height and number of leaves per plant was recorded from plot receiving nitrogen @ 120 kg/ha combined application with Sulphur @ 40 kg/ha, value of 213.88 cm and 13.53, respectively while minimum was recorded from plot receiving 0 kg/ha nitrogen with application of Sulphur of 20 kg/ha.

Nitrogen levels significantly influenced growth attributes. Growth attributes responded to increasing dose of nitrogen. Maize has shown almost all universal response to nitrogen as it plays an important role in improving growth and yield attributes and final grain yield. Nitrogen constitutes 40 to 50 per cent of dry matter of protoplasm in plant cell and is essential element for its proper growth and development. It is also essential for building of protein unit and early establishment of leaf area capable of synthesizing the food through photosynthesis and ultimately resulting in higher economic yield. The improvement in growth parameter with application of 120 kg N/ha might have resulted in better and timely availability of N for their utilization by plant as judged from nitrogen content of straw. Nitrogen is considered a vitally important plant nutrient. In addition to its role in the formation of proteins, nitrogen is an integral part of chlorophyll which is the primary absorber of light energy needed for photosynthesis. Besides these, it is also a constituent of certain organic compounds of physiological importance. Under the present investigation, profound influence of N as component of fertility management, on crop growth seen to be due to maintaining congenial nutritional environment of plant system on account of their greater availability from soil media.

Increase in plant height with increasing levels of N could be attributed to the fact that nitrogen helps in higher photosynthetic activity, cell and internodal elongation and maintenance of higher auxin levels, which might have resulted in the plants of taller stature. Similar results of increase in plant height with increasing levels of N application were reported by Ravi *et al*. (2012) [18] and Chaudhary *et al.* (2013) [5].

The significant improvement in nutrient status of plant parts might have resulted in greater synthesis of amino acids, proteins and growth promoting hormones, which leads to enhanced the meristematic activity and increased cell division and their elongation. Further increased chlorophyll content accompanied with more functional leaves and leaf area under the application of 120 kg N/ha might have increased interception, absorption and utilization of radiant energy which in turn increased photosynthesis and thereby increase plant height, number of leaves per plant and finally results in better growth.

Table 1: Effect of nitrogen and sulphur on growth and yield of maize

Treatment	Plant height (cm)	Number of leaves/plant	Number of rows per cob	Number of grains per cob
	Effect of nitrogen			
N_0	157.89	11.04	10.64	211.78
N_1	183.96	12.24	13.71	232.67
N_2	191.39	12.73	14.18	245.47
N_3	206.15	13.16	14.89	291.84
S.Em±	1.44	0.13	0.24	1.89
C.D.	4.24	0.39	0.71	5.55
	Effect of Sulphur			
S_1	173.93	11.85	12.65	235.87
S_2	186.49	12.32	13.33	244.40
S_3	194.12	12.72	14.08	256.05
S.Em±	1.25	0.11	0.21	1.64
C.D.	3.67	0.34	0.61	4.80
	Interaction effect between nitrogen and Sulphur			
N_0S_1	123.54	9.80	8.73	203.40
N_0S_2	180.49	12.00	13.47	226.40
N_0S_3	190.75	12.67	14.07	241.93
N_1S_1	200.95	12.93	14.33	271.73
N_1S_2	166.56	11.47	10.87	212.07
N_1S_3	184.81	12.13	13.80	234.87
N_2S_1	190.97	12.67	14.20	243.80
N_2S_2	203.63	13.00	14.47	286.87
N_2S_3	183.56	11.87	12.33	219.87
N_3S_1	186.60	12.60	13.87	236.73
N_3S_2	192.45	12.87	14.27	250.67
N_3S_3	213.88	13.53	15.87	316.93
S.Em±	2.50	0.23	0.42	3.28
C.D.	7.34	0.67	1.22	9.61

Better growth and development of maize plants due to higher levels of Sulphur dose would have been due to multiple roles of S in protein and carbohydrate metabolism of plants by activating a number of enzymes which participate in dark reaction of photosynthesis hence increases the plant height and dry matter was observed with increased dose of S application. Rahul *et al*., (2017) [14] reported highest plant growth of maize at higher dose of S application. Choudhary *et al*. (2013) [5] and Rahul *et al*., (2017) [14] also reported an increase in the plant growth of maize with increasing levels of Sulphur. It is fact that nitrogen and Sulphur help in higher photosynthetic activity, cell and internodal elongation and maintenance of higher auxin levels, which might have resulted in the plants of taller stature. Similar results of increase in plant height with increasing levels of N and S application were reported by Chaudhary *et al*. (2013) [5], Daoudi and Rajesh (2017) [6] and Pavithra *et al*., (2018) [13].

Data revealed that maximum number of rows per cob, number of grains per cob, length of cob, grain and stalk yield per hectare (14.89, 291.84, 13.68 cm, 46.64 q/ha and 58.29 q/ha, respectively) were recorded in plots treated with the application of nitrogen @ 120 kg/ha (N_3) while, lowest values were observed in plot that received no nitrogen. Similarly, application of Sulphur @ 40 kg/ha gave maximum number of rows per cob, number of grains per cob, length of cob, grain and stalk yield per hectare with the respective of 14.08, 256.05, 12.67 cm, 38.69 q/ha and 49.08 q/ha, respectively.

Data revealed that interaction effect of nitrogen and Sulphur significantly affected yield attributes was found significant. Similarly, in interaction the maximum number of rows per cob, number of grains per cob, length of cob, grain and stalk yield per hectare was recorded from plot receiving nitrogen @ 120 kg/ha combined application with Sulphur @ 40 kg/ha, value of 15.87, 316.93, 15.28 cm, 52.03 q/ha and 63.68 q/ha, respectively. While, minimum was recorded from plot receiving 0 kg/ha nitrogen with application of Sulphur of 40 kg/ha. Interaction effect of nitrogen and Sulphur for number of cobs per plant was found non- significant.

Table 2: Effect of nitrogen and sulphur on growth and yield of maize

Treatment	Length of cob (cm)	Grain Yield (q/ha)	Stalk Yield (q/ha)	Protein content (%)
	Effect of nitrogen			
N_0	10.49	22.52	29.35	9.70
N_1	11.58	32.95	43.74	10.00
N_2	12.22	38.42	50.28	10.61
N_3	13.68	46.64	58.29	11.45
S.Em±	0.16	0.60	0.77	0.05
C.D.	0.48	1.75	2.25	0.14
	Effect of Sulphur			
S_1	11.42	31.65	41.08	10.14
S_2	11.89	35.06	46.09	10.53
S_3	12.67	38.69	49.08	10.65
S.Em±	0.14	0.52	0.67	0.04
C.D.	0.41	1.52	1.95	0.12
	Interaction effect between nitrogen and Sulphur			
N_0S_1	10.03	17.37	22.22	9.53
N_0S_2	11.24	30.24	39.61	9.85
N_0S_3	12.12	35.93	48.21	10.23
N_1S_1	12.28	43.07	54.26	10.95
N_1S_2	10.41	24.48	32.39	9.78
N_1S_3	11.43	33.58	44.66	10.04
N_2S_1	12.26	37.36	50.38	10.77
N_2S_2	13.46	44.84	56.93	11.54
N_2S_3	11.03	25.73	33.42	9.80
N_3S_1	12.08	35.01	46.96	10.10
N_3S_2	12.27	41.98	52.25	10.84
N_3S_3	15.28	52.03	63.68	11.85
S.Em±	0.28	1.04	1.33	0.08
C.D.	0.83	3.04	3.90	0.25

It was emphasized that nitrogen level of 120 kg N/ha did cause a significant improvement in overall growth of the crop expressed in terms of plant height, leaf area index, functional leaves, chlorophyll content, stem diameter and dry matter accumulation by virtue of increased photosynthetic efficiency. Thus, greater availability of photosynthates, metabolites and nutrients to develop reproductive structures seems to have resulted in increased productive plants, number of grains per cob, number of cobs per plant, cob length, cob girth, test weigh with nitrogen levels of 120 kg/ ha. The result of the present investigation is in close accordance with the findings of Bharvand *et al*., (2014) [4] and Ramhari *et al*., (2020) [16].

Nitrogen helps in maintaining higher auxin levels which in turn have favorable effect on cell enlargement, resulting in higher plant height and LAI resulting in better interception and utilization of radiant energy, leading to higher photosynthetic rate, which ultimately resulted in higher accumulation of dry matter. In addition to this, nitrogen is a major constituent of chlorophyll, whose intensity is known to increase with added N supply, which results in more efficient photosynthesis, accumulating higher level of biomass. Enhanced dry matter production with adequate supply of nitrogen, as evidenced in this investigation corroborates the findings of Mathukia *et al*. (2014) [11] in sweet corn, Verma and Singh (2014) [22] in popcorn and Rao *et al*. (2014) [17], Jeet *et al*., (2017) [10] in maize.

Higher number of grains /cob was recorded with S3 @ 40 kg/ ha. These findings were in line with the findings of Gahlout *et al*. (2010) [8], who reported that improvement of vegetative structures for nutrients absorption and photosynthesis, strong sink strength through development of reproductive structures and production of assimilates under influence of applied Sulphur maintained and balanced source to sink ratio which might have resulted in increased yield attributes of maize. This report was substantiating with Srinivas Rao *et al*. (2010) [20] and Shivran *et al*. (2013) [19].

More number of bigger size cobs might have accommodated number of grains providing sufficient space for development of individual grain, leading to higher test weight with Sulphur application resulting in higher grain weight. Similar observations were made by Dibaba *et al*. (2013) [7] and Padma *et al*., (2018) [12].

Adequate supply of N and S is essential for optimizing partitioning of dry matter between grain and other parts of the maize plant. Optimum utilization of solar radiation, higher assimilates production and its conversion to starch results in higher biomass, seed yield leading to higher harvest index. These observations corroborate with those made by Raman and Suganya, (2018) [15] and Vijaya *et al*., (2019) [27]. Nitrogen and Sulphur are essential nutrients required for the promotion of the meristematic and physiological activities such as leaf spread, root development, plant dry matter production, leading to efficient absorption and translocation of water and nutrients and interception of solar radiation. These activities promote higher photosynthetic activities leading to the production of enough assimilates for subsequent translocation to various sink and there by leading to production of higher sink components like cob length, cob girth, 1000- grain weight, number of cobs/ plant and number of grains per cob. The results are also in conformity with the findings of Ravi *et al*. (2012) [18].

The protein content of maize noticed under highest level of nitrogen @ 120 kg /ha combined application of Sulphur @ 40 kg S/ha. Nitrogen is an integral part of protein molecules, there was an increase in grain protein content with increase in uptake of nitrogen and Sulphur by maize as evident from the uptake data. Sulphur is best known for its role in the formation of Sulphur containing amino acids *viz*., methionine and cysteine.

Conclusion

Based upon this experiment it is concluded that application of higher level of nitrogen at the rate of 120 kg/ ha combined application with Sulphur at the rate of 40 kg/ ha recorded the maximum growth and grain yield of maize.

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