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To study the effect of sulphur and zinc on yield of maize crop under maize-wheat cropping system

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Abstract
The present field was carried out during 2018-19 and 2019-20 at Student Instructional Farm, Department of Agronomy, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur with main objective to find out the technically feasible, qualitative, productive and economically viable effect of Sulphur and Zinc maize-wheat cropping rotation and to evaluate the response of these treatments on maize-wheat cropping system. The soil of university research farm is an Entisol with sandy loam texture, deficient in organic carbon available N and available Zn but medium in case of available P, K and available S. The pH and EC of soil are in normal range and responsive to macro and micro nutrients applied in balanced manner in view of the deficiency of these nutrients and vital metabolic role of the above nutrients in maize-wheat cropping system and studied in respective manners. 9 treatments comprises of *viz.*, T_1 - Control, T_2- 50 % NPK, T_3- 100 % NPK, T_4- 50 % NPK + S, T_5- 100 % NPK + S, T_6- 50 % NPK + Zn, T_7 -100 % NPK + Zn, T_8 - 50 % NPK + S + Zn and T_9 - 100 % NPK + S + Zn. Results recorded significantly maximum grain, stover and biological yield, and harvest index in treatments comprising S and/or Zn with 50 or 100 % RDF both the year, however, it was highly significant over control. The highest grain and stover yield was registered with the application of T_9 (100% RDF+S+Zn) which remained at par with T_5 and significantly superior over rest of the treatments on both the years and pooled mean basis. The application of T_8 (50%RDF+S+Zn) recorded significantly higher yield over all the treatments of 50% RDF but found at par with T_4 (50%RDF+S) during course of investigation.

Keywords: Control, T_2- 50 % NPK, T_3- 100 % NPK, T_4- 50 % NPK + S, T_5- 100 % NPK + S, T_6- 50 % NPK + Zn, T_7 -100 % NPK + Zn, T_8 - 50 % NPK + S + Zn and T_9 - 100 % NPK + S + Zn

Introduction
Maize-wheat crop rotation is one of the major cropping systems adopted in India, covering around 1.8 million hectares area that contributes 3% food grain production in India, mainly in the Indo-Gangetic plains of the country. Fertile revenue alluvial soils are best for Maize-wheat cultivation. Among different maize based cropping systems, maize-wheat rank first and it is third most important cropping system after rice-wheat and rice-rice. Maize and wheat are the main source of food energy in the world and also contain significant amounts of carbohydrates, proteins, vitamins and minerals that are essential to human health. It is, considered to be the most important option for diversifying agriculture in the upland ecology of India. Maize being a C4 plant species has a high production potential compared to any other cereal crop.

It is well known that maize is a heavy nutrient feeder and also a very efficient converter of solar energy to dry matter. Maize *(Zea mays* L.) is consumed both as food and as feed and is also required by various industries to produce agro-products. It accounts for almost 8 and 25% of the world's area and production of cereals, respectively. It occupies an important position in the world economy and trade as a food, feed and industrial grain crop (Lal 2001) In India, maize is grown in an area of 9.0 million hectares with a production of 26,14 million tons and a productivity of 2629,28 kg ha^{-1} (Government of India, 2018). Ten states in India represents around 80% of the total area of maize grown, Karnataka (15%) is the largest state for maize cultivation followed by Rajasthan (13%) and Madhya Pradesh (10%). The maize-wheat crop system ranks first among the various maize-base farming systems (Jat *et al.*, 2011) [21]. The balanced fertilization is a key component of nutrient management and plays a key role in improving crop production. The balanced application of nutrients such as N, P, K, S and Zn etc. is essential for major processes of plant development and yield formation; (Randhwa and Arora 2000) [24].

Phosphorus (P) is one of the most important nutrients to improve crop yield. In an attempt to achieve higher yield, farmers have resorted to using higher than the recommended levels of fertilizer in many areas in India.

Optimal P-fertilization in the wheat-maize cropping system is one of the effective measures to improve crop yield and to protect the environment from surface water eutrophication. Potassium (K^+) is one of the limiting nutrients considered important for the growth and production of crop yields. While it does not make an integral part of the initial or intrinsic cellular part of the plant, it is the most abundant cation in plants and is associated or involved in many physiological processes that promote plant growth and development. Water relation, Photosynthesis, assimilate transportation and enzyme activation all can be impacted by potassium.

Sulphur (S) is now recognized as the 4th major plant nutrient. Sulphur serves many functions in plants. It is used in the formation of amino acids, protein, and oils. It is necessary for chlorophyll formation, promotes nodulation in legumes, helps to develop and activate certain enzymes and vitamin and is a structural component of the 21 amino acids that form protein. It has become increasingly clear that oilseeds require S in high amounts followed by pulses, forages, tuber crops and cereals. Numerous field experiments clearly showed that more than 40 crops have responded to S fertilization with mean yield increase ranging from 14% to 74%. The large body of evidence indicates that S requirements must be an integral part of balanced fertilization for obtaining optimum crop yields of high quality (oil, protein, fatty acids, and reduced nitrate in foliage). S fertilization is a viable strategy to improve the absorption and usage performance of N, P, K and Zn, and to inhibit plant uptake of harmful toxic elements such as Se and Mo due to the synergistic interaction between the sulphur and the former and the latter. Main steps required to maximize the usage of sustainable crop productivity and to minimize the environmental risks.

Materials and Methods

The experiment was conducted at Students' Instructional Farm, Department of Agronomy Chandra Shekhar Azad University of Agriculture & Technology, Kanpur and itwas in the alluvial tract of Indo - Gangetic plains in central part of Uttar Pradesh between 25 ^{0}26' to 26^{0}58' North latitude and 79 ^{0}31' to 80 ^{0}34' East longitude at an elevation of 125.9 m above mean sea level. The irrigation facilities are available on the farm. This zone has semi-arid climatic conditions, having alluvial fertile soil. The normal rainfall of the area is about 890 mm per annum. Most of the rains are received from mid-June to end of September. The winter months are cooler with occasional rains and frost during last week of December to mid-January. The temperature in the month of May and June may go up to 44-47 ^{0}C or beyond and during winter it may go down to 2-3 ^{0}C. Mean relative humidity (7.00 AM) remains nearly constant at about 80- 90% from July to end of March and after March slowly declines to about 40-50% by the end of April and remains constant at 80% up to May. The weekly distribution of maximum and minimum temperatures (^{0}C), relative humidity (%), wind velocity (km/hrs.), evaporation rate (mm/day) and total rainfall (mm). Maize was grown during kharif which was followed by wheat during *rabi* of 2018-19 and 2019- 2020 with a view to compare production potential of maize and wheat under management of RDF through the use of inorganic fertilizers, on wheat crop to find out the economic viability of the system under irrigated conditions of Central Uttar Pradesh. The experimental details are given below: The experiment was carried out in Randomized Block Design (RBD) having three replications and nine integrated nutrient management combinations *i.e.* T_1 Control, T_2 50 % NPK, T_3 100 % NPK, T_4 50 % NPK + S, T_5 100 % NPK + S, T_6 50 % NPK + Zn, T_7 100 % NPK + Zn, T_8 50 % NPK + S + Zn and T_9 100 % NPK + S + Zn.

Results and Discussion

Yield of Maize Crop

Effect of different inorganic treatments on grain and stover yield of maize during 2018-19 and 2019-20 of maize crop were analyzed statistically the results of both years have been presented in Table-1.

Grain yield (q ha^{-1})

The perusal of data pertaining to grain yield as furnished in table 1 revealed that there was a significant variation due to application of different treatments. It varied from 16.35 to 27.53 q ha^{-1} and 16.20 to 28.81 q ha^{-1} during first and second years, respectively. The yield followed increment pattern with increasing doses of fertilizer from 50 to 100%. The highest yield was registered with the application of T_9 (100%RDF+S+Zn) but remained at par with T_5 and significantly superior over rest of the treatments on pooled mean basis. The application of S along with RDF of NPK significantly enhanced the yield over T_3 (100%RDF) but shows at par effect with T_7 (100%RDF+Zn). The application of T_8 (50%RDF+S+Zn) in maize recorded significantly higher yield over all the treatments of 50% RDF but found at par with T_4 (50%RDF+S) during course of investigation. On pooled mean basis, the application of T_9 contributed by 73.14, 15.40, 9.40 and 5.38 % over the treatments of T_1, T_3, T_7 and T_5. In case of 50% RDF, the application of T_8 contributed to the order of 48.25, 16.80, 10.39 and 5.79 % over T_4, T_6 (50%RDF+Zn), T_2 (50%NPK) T_1 respectively. Similar finding was also reported that grain yield (3.48 t ha^{-1}) with 120 kg ha^{-1} nitrogen over 80 and 40 kg N ha^{-1}. Kumar and Tripathi (2010). Similar findings were observed by Choudhary *et al*., 2007, Kumar *et al.* (2009), Jaime and Viola (2011).

Stover yield (q ha^{-1})

The data regarding Stover yield have been depicted in table 1. The stover yield ranged from 76.17 to 74.55 q ha^{-1} and 45.68 to 77.81 q ha^{-1} during first and second years, respectively. It is clear from the table that the application of various treatments in maize significantly increased the stover yield during both the years of study. The highest stover yield was recorded with the application of T_9 (100% RDF+S+Zn) followed by T_5 (100%RDF+S) and T_7 (100%RDF+Zn). The minimum value was noted with the application of T_1. In case of 50 %RDF, the application of T_8 improved the yield over all the treatments under investigation. However, it exceeded the yields obtained in treatment of T_3. The application of S either with 50 or 100 % RDF recorded higher yield over all the treatments except T_9 which was numerically higher but remained on par with T_7 during course of study undertaken. On pooled mean basis, the application of T_9 contributed by 65.89, 14.24, 8.41 and 4.88 % over the treatments of T_1, T_3, T_7 and T_5. Whereas, in case of 50% RDF, the application of T_8 contributed to the order of 43.73, 16.31, 10.07 and 5.66% over T_4, T_6, T_2, T_1 respectively. Similar finding was also reported by Bindhani *et al.* (2007), Kumar and Tripathi (2010), Kar *et al.* (2006).

Table 1: Effect of different inorganic treatments on grain and stover yield of maize during 2018-19 and 2019-20

Treatments combinations	Grain yield (q ha^{-1})			Stover yield (q ha^{-1})		
	2018-19	2019-20	Pooled Mean	2018-19	2019-20	Pooled Mean
T_1 Control	16.35	16.20	16.27	46.17	45.68	45.92
T_2 50% NPK	20.13	21.18	20.65	55.40	58.15	56.77
T_3 100 NPK	23.85	24.97	24.41	65.24	68.13	66.68
T_4 50% NPK+S	22.25	23.35	22.80	61.05	63.94	62.49
T_5 100 % NPK +S	26.16	27.30	26.73	71.20	74.07	72.63
T_6 50% NPK + Zn	21.31	22.39	21.85	58.59	61.40	59.99
T_7 100% NPK + Zn	25.20	26.31	25.75	68.76	71.797	70.27
T_8 50 % NPK + S + Zn	23.51	24.73	24.12	64.44	67.62	66.03
T_9 100 % NPK + S + Zn	27.53	28.81	28.17	74.55	77.81	76.18
SE (d)	1.08	1.36	0.84	1.67	2.17	1.33
CD (0.05%)	2.30	2.88	1.72	3.56	4.61	2.71

Biological yield (q ha^{-1})

The data regarding biological yield have been depicted in table 2. It is clear from the table that the application of various treatments in maize significantly increased the biological yield during both the years of study. The biological yield ranged from 62.52 to 102.02 q ha^{-1} and 61.88 to 106.62 q ha^{-1} during first and second years, respectively. The highest biological yield was recorded with the application of T_9 (100% RDF+S+Zn) followed by T_5 (100%RDF+S) and T_7. The minimum value was noted with the application of T_1. In case of 50 %RDF, the application of T_8 improved the yield over any treatments of 50 % RDF under investigation. However, it exceeded the yields obtained in treatment of T_3. The application of S either with 50 or 100 % RDF recorded higher yield over all the treatments except T_9 which was numerically higher but remained on par with T_7 (100% RDF+Zn) during course of study undertaken. On pool basis, the maximum biological yield (104.35 q/ha) was recorded however remained on par with T_5 and T_7. The minimum biological yield value was showed that 62.20 qha^{-1} with the application of T_1. Similar findings were observed by Choudhary *et al*., 2007, Kumar *et al.* (2009), Jaime and Viola (2011).

Table 2. Effect of different inorganic treatments on biological and harvest index of maize during 2018-19 and 2019-20

Treatments combinations	Biological yield (qha^{-1})			Harvest Index (%)		
	2018-19	2019-20	Pooled Mean	2018-19	2019-20	Pooled Mean
T_1 Control	62.52	61.88	62.20	26.15	26.18	26.16
T_2 50% NPK	75.53	79.33	77.43	26.65	26.70	26.67
T_3 100 NPK	89.09	93.10	91.09	26.77	26.82	26.79
T_4 50% NPK+S	83.30	87.29	85.29	26.71	26.75	26.73
T_5 100 % NPK +S	97.36	101.37	99.36	26.87	26.93	26.90
T_6 50% NPK + Zn	79.90	83.79	81.48	26.67	26.72	26.69
T_7 100% NPK + Zn	93.96	98.10	96.03	26.82	26.87	26.84
T_8 50 % NPK + S + Zn	87.95	92.35	90.15	26.73	26.78	26.75
T_9 100 % NPK + S + Zn	102.08	106.62	104.35	26.97	27.2	26.99
SE (d)	2.99	3.38	2.19	0.17	0.18	0.12
CD (0.05%)	6.34	7.17	4.45	0.37	0.39	0.25

Harvest Index (%)

The data regarding harvest index has been presented in table 2. It clearly revealed that the HI significantly influenced due to different inorganic treatments during both the years. The application of T_9 (100% RDF+S+Zn) recorded maximum mean values of harvest index (27.2). Where as, (T_1) control gave the lowest value of harvest index during first and second year of experimentation. It varied from 26.15to 26.97 and 26.18 to 27.12 % during first and second years, respectively. It was further noted that the graded application of RDF from 50 to 100 % further increased the harvest index. The data clearly indicated that addition of RDF from 50 to 100% with Sulphur and Zinc significantly improved the harvest index during both the years. However, remained at par with T_5 (100%RDF+S) and T_7 (100%RDF+Zn) and significantly superior over rest of the treatments on pooled mean basis. Similar finding was also reported by Kumar and Tripathi (2010) conducted a field experiment on nitrogen management in baby corn at Kanpur and reported that increasing levels of nitrogen increased growth, yield attributes and yield of baby corn significantly up to 150 kg/ha where highest of 1682 kg/ha fresh baby corn was produced.). Similar findings were observed by Choudhary *et al*., 2007, Kumar *et al.* (2009), Jaime and Viola (2011).

Summery and Conculation

- The highest yield was registered with the application of T_9 (100% RDF+S+Zn) but remained at par with T_5 and significantly superior over rest of the treatments on pooled mean basis. On pooled mean basis, the application of T_9 contributed by 73.14, 15.40, 9.40 and 5.38 % over the treatments of T_1, T_3, T_7 and T_5. Whereas, in case of 50% RDF, the application of T_8 contributed to the order of 48.25, 16.80, 10.39 and 5.79 % over T_4, T_6 (50%RDF+Zn), T_2 (50%NPK) T_1 respectively.
- The highest stover yield was recorded with the application of T_9 (100% RDF+S+Zn) followed by T_5 (100%RDF+S) and T_7 (100%RDF+Zn). The minimum value was noted with the application of T_1 (Control). The highest stover yield was recorded with the application of T_9 (100% RDF+S+Zn) followed by T_5 (100%RDF+S) and T_7 (100%RDF+Zn) during investigation. The application of S either with 50 or 100 % RDF recorded higher yield over all the treatments except T_9 which was numerically higher but remained on par with T_7 during

course of study undertaken. On pooled mean basis, the application of T_9 contributed by 65.89, 14.24, 8.41 and 4.88 % over the treatments of T_1, T_3, T_7 and T_5 during investigation. Yields of maize cropin terms of biological, maize grain, and maize stover yield per unit area was maximum under T_9 (100%NPK+S+Zn)respectively.The yield followed increment pattern with increasing doses of fertilizer from 50 to 100%. The application of S along with RDF significantly enhanced the yield over T_3 (100%RDF) but shows at par effect with T_7 (100%RDF+Zn) respectively. The highest biological yield was recorded with the application of T_9 (100% RDF+S+Zn) followed by T_5 (100%RDF+S) and T_7 respectively.

- The application of S either with 50 or 100 % RDF recorded higher yield over all the treatments except T_9 which was numerically higher but remained on par with T_7 (100%RDF+Zn) during course of study undertaken. The application of T_9 (100% RDF+S+Zn) recorded maximum mean values of harvest index (27.2). The minimum value of harvest index was computed under the plots applied with T_2 through (50% RDF) during both the years and on pooled basis. The data clearly indicated that addition of RDF from 50 to 100% with Sulphur and Zinc significantly improved the harvest index during both the years.

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