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Exploring the efficiency of calcium and potassium thiosulphate on yield and economics of winter maize

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Abstract

A field experiment was conducted during *rabi* season of 2019-20 to assess the influence of different level of calcium and potassium thiosulphate on growth, yield and yield attributing characters of maize (*Zea mays* L.) at Crop Research Centre, RPCAU, Pusa, Bihar. The experiment was conducted in randomized block design with four replications and twelve treatments at different level of calcium and potassium thiosulphate @ 0, 15, 30 & 60 L/ha were applied according to treatments. Nitrogen, phosphorus and potassium were applied as urea, urea phosphate and potassium sulphate in all the treatments, respectively. In treatments T_1 to T_7, the Calcium and potassium thiosulphate were applied through drip, while in treatment T_8 to T_{12} calcium and potassium thiosulphate were applied as band placement along with potassium sulphate. The experimental results indicated that treatment T_7 (150:75:38 N-P_2O_5-K_2O kg/ha + 30 L CaTS/ha + 30 L KTS/ha- Drip) produced significantly higher weight of cobs plant^{-1} (150.1 g), weight of grains cob^{-1} (121.6 g), weight of stones cob^{-1} ((21.3 g) and 100-grain weight (32 g), maximum grain yield (9063.0 kg ha^{-1}), stover yield (7951.3 kg ha^{-1}) and stone yield (1591.7 kg ha^{-1}). Economics of different treatments indicated that by higher grain yield, treatment T_7 (150:75:38 N-P_2O_5-K_2O kg/ha + 30 L CaTS/ha + 30 L KTS/ha- Drip) exhibited maximum gross return, net return and B:C ratio of ₹ 184163 ha^{-1}, ₹ 124905 ha^{-1} and 2.11 respectively.

Keywords: Calcium thiosulphate, Potassium thiosulphate, *rabi* maize

Introduction

Queen of Cereals which is also identified as Miracle crop and popularly known as Maize (*Zea mays* L.) is one of the most common multipurpose monocotyledonous C_4 crops with greater adaptability to a wide range of soil and climatic conditions. Queen of cereals is the third largest essential crop after rice and wheat in terms of areas and production in India, cultivating in 9. 72 mha area with the total production of 30.20 million tonnes and now it ranks 4th in terms of area and 7th in terms of production worldwide. In India, maize productivity is around 3.11 tonnes per ha which is slightly more than one half of the world average (5.73 tonnes ha^{-1}) productivity and contributes 2.7% to the total world production in maize (Anonymous, 2021) [1]. In India maize is traditionally a *kharif* crop of northern India. Cultivation of maize during *rabi* season (winter maize) was originated from Bihar in 1961. Winter maize cultivation is blistering rapidly to other regions of the country. The production potential of winter maize is highest due to photo-thermo-insensitive character, extended life span of the plant, especially the reproductive phase, no water logging condition and minimum infestation of insect, pest and diseases (Anonymous, 2018) [2]. Our country's climatic conditions and existing varieties are ideal for increasing maize production. Fertilizer plays an important role in increasing maize productivity, accounting for 40-45 percent of the total. Using a balanced and appropriate source of potassium, calcium, and sulphur is crucial at all stages of maize growth and yield. Potassium thiosulphate (KTS) is a clear liquid fertilizer that is neutral to basic in nature, chlorine free and contains 25% potassium and 17% sulphur. It has a density of 1.46 g/cm^3. Calcium thiosulphate (CaTS) is a clear liquid solution containing 10% S and 6% Ca, density 1.25 g/cm^3. Potassium is one of the major nutrients needed to complete the life cycle of all plants. It is required in greater quantities than phosphorus inside of the live plant tissues. It had a significant impact upon maize yield and grains quality. It helps to regulate the amount of water in the plant. Potassium triggers many enzymes and is essential for maintenance of potential gradient across the cell membrane and the plant cells turgidity. Because of its importance in turgor maintenance, K is required for maximum leaf extension and stem elongation.

Potassium and its application timings have a significantly enhances on maize growth *viz*. tasseling, silking, flag leaf area, maturity and grain yield production (Asif *et al*., 2007) [3]. Sulphur is secondary macronutrients (along with Ca and Mg) which is needed by plants for the synthesis of some amino acids (methionine and cysteine), proteins and photosynthesis process. It has a direct effect on the plant's various biochemical reaction and helps in chlorophyll formation. Sulphur has not only improved the nutritional value of cereal crops but also increase crop production (Zhao *et al*., 2001) [4]. Calcium has a number of important functions, including influencing the division of meristematic cells and their consequent extension, which is required for the growth of both roots and shoots. In the last two decades, calcium has been identified as a crucial nutrient responsible for the growth and development of the crops.

Materials and Methods

A field experiment was conducted during *rabi* season of 2019-20 at the RPCAU, Pusa, Bihar. The soil of the experimental field was calcareous in nature containing 26% free $CaCO_3$, sandy loam in texture, alkaline in nature with a pH of 8.68 and EC 0.472 dS/m. The soil contained low in organic carbon (0.42%), available nitrogen (218.4kg ha^{-1}), while medium in available phosphorus (35.6 kg ha^{-1}), potassium (181.2 kg ha^{-1}) and sulphur (12.5 mg kg^{-1}). The experiment was conducted in randomised block design with twelve treatment and replicated four times (Table 1). DKC-9081 variety of maize was sown according to the date decided in the treatment, planted in paired row system with a spacing of 75/45 cm (RR) and 20 cm (PP), with the seed rate of 20 kg ha^{-1} at 3-4 cm depth. Nitrogen and phosphorus were applied as urea and urea phosphate through fertigation in all the treatments. In treatments T_1 to T_7, the potassium was applied in the form of SOP in drip, while in treatment T_8 to T_{12} potassium as SOP was applied as band placement. Calcium and potassium thiosulphate @ 0, 15, 30 & 60 L/ha were applied according to treatments. At each time, pre-calculated fertilizers were dissolved in water and applied through fertigation and band placement as per technical programme. In case of conventional methods, nitrogen and potassium were applied in three equal splits, at planting, at 28 and 56 DAS. All recommended agronomic practices (weeding, hoeing, pesticides, irrigation etc.) were kept uniform for all the treatments and were carried out throughout the growing season, when required. During the experiment observations were recorded using the standard procedure for each parameter.

Table 1: Treatment details of experiment

Treatments
T_1: Fertigation of RDF: 150:75:60 N-P_2O_5-K_2O kg/ha (Drip)
T_2: 150: 75:54.5 N-P_2O_5-K_2O kg/ha + 15 L KTS/ha (Drip)
T_3: 150: 75: 49 N-P_2O_5-K_2O kg/ha + 30 L KTS/ha (Drip)
T_4: 150:75:38 N-P_2O_5-K_2O kg/ha + 60 L KTS/ha (Drip)
T_5: 150:75:60 N-P_2O_5-K_2O kg/ha + 15 L CaTS/ha (Drip)
T_6: 150:75:60 N-P_2O_5-K_2O kg/ha + 30 L CaTS/ha (Drip)
T_7:150:75:38 N-P_2O_5-K_2O kg/ha + 30 L CaTS/ha + 30 L KTS/ha (Drip)
T_8: Conventional recommended dose N-P-K 150:75:60 N-P_2O_5-K_2O kg/ha (band application)
T_9: 150:75:38 N-P_2O_5-K_2O kg/ha + 30 L KTS/ha (band application)
T_{10}: 150:75:60 N-P_2O_5-K_2O kg/ha + 30 L CaTS/ha (band application)
T_{11}: 150:75:49 N-P_2O_5-K_2O kg/ha + 60 L KTS/ha (band application)
T_{12}: 150:75:38 N-P_2O_5-K_2O kg/ha + 30 L CaTS/ha+ 30 L KTS/ha (band application)

Results and Discussion

Effect of different treatments on yield attributes characters and yield

Number of cobs plant^{-1}

Statistical analysis of the data (Table 2) indicated that calcium thiosulphate (CaTS) and potassium thiosulphate (KTS) level in combination was not influenced significantly. Since, the numbers of cob per plant was directly related to genetic factors, and each plant carried only one cob in all treatments. As a result, no differences were recorded in the present experiment.

Weight of cobs plant^{-1} (g)

Mean data (table 2) indicated that calcium thiosulphate (CaTS) and potassium thiosulphate (KTS) level in combination had significant effect on weight of cobs plant^{-1} of maize. Significantly highest weight of cobs plant^{-1} with application of graded doses of 30 L CaTS and 30 L KTS along with NPK through drip irrigation which was on par with T_3 (NPK with 30 L KTS/ha-Drip), T_4 (NPK with 60 L KTS/ha-Drip), T_6 (NPK with 30 L CaTS-Drip), (T_9-30 L KTS/ha- band application), T_{11}- (T_9-60 L KTS/ha- band application) and T_{12}- (NPK with 30 L CaTS/ha+30 L KTS/ha -band application). This might be due to adequate supply of K under proper moistures partitioning of biomass to the reproductive parts. Potassium also enhances the activity of enzymes involved in carbohydrates build up and translocation of assimilates from source to sink, resulted in heavier cobs weight. These results are in accordance with Irfanullah *et al.* (2017) [5] and Equar *et al*. (2016) [6].

Weight of grains cob^{-1} (g)

Application of graded doses of 30 L CaTS and 30 L KTS along with NPK through drip irrigation recorded the highest Weight of grains cob^{-1} (121.6 g) (table 2) which was on par with T_3 (NPK with 30 L KTS/ha-Drip), T_4 (NPK with 60 L KTS/ha-Drip), T_6 (NPK with 30 L CaTS-Drip), (T_9-30 L KTS/ha- band application), T_{11}- (T_9-60 L KTS/ha- band application) and T_{12}- (NPK with 30 L CaTS/ha+30 L KTS/ha -band application). These finding were supported by Irfanullah *et al.* (2017) [5], Equar *et al*. (2016) [6] and Zare *et al.* (2014) [7].

Weight of stones cob^{-1} (g)

The weight of stones per cob (21.3 g) recorded significantly higher (table 2) in treatment with application of NPK with 30

L CaTS and 30 L KTS through drip irrigation system which was statistically at par with all treatment except treatment T_1- fertigation of RDF:150:75:60 NPK kg/ha-Drip (18.6 g cob^{-1}) and conventional recommended dose 150:75:60 NPK kg/ha-band application (T_8).

100 grain weight (g)

The highest 100-grain weight (32 g) (table 2) was found in 150:75:38 NPK kg/ha + 30 L CaTS/ha + 30 L KTS/ha- Drip (T_7), which remained statistically at par to the treatment T_3- NPK with 30 L KTS/ha- Drip (31 g), T_4- 150:75:38 NPK kg/ha with 60 L KTS/ha- Drip (31 g), T_6- 150:75:60 NPK kg/ha + 30 L CaTS/ha- Drip (30 g), T_9- 150:75:38 NPK kg/ha + 30 L KTS/ha- band application (30 g), T_{11}- 150:75:49 NPK kg/ha + 60 L KTS/ha- band application (30 g) and T_{12}- 150:75:38 NPK kg/ha + 30 L CaTS/ha+ 30 L KTS/ha- band application having (31 g). This might be due to higher nutrient uptake and better nutrient translocation to sink under potassium doses. These findings were supported by Ali *et al.* (2020) [8], Gnanasundari *et al.* (2018) and Hussain *et al.* (2007) [10].

Grain yield (kg ha^{-1})

Fertigation (drip irrigation) with NPK alone and NPK with KTS and CaTS showed the variation in grain yield from 7009.5 to 9063.0 kg ha^{-1} (Table 3, fig. 1). The increase in grain yield 2053.5 kg ha^{-1} due application of KTS and CaTS through drip irrigation over control. Application of NPK along with 30 L KTS/ha + 30 L CaTS/ha (T_7) showed maximum increase in grain yield (29.3%) followed by T_4- NPK with 60 L KTS/ha (24.5%), T_3- NPK with 30 L KTS/ha (23.2%), T_6- NPK with 30 L CaTS/ha (19.7%) over alone application of NPK (T_1) through drip irrigation. The grain yield varied from 6729.5 to 8546.0 kg ha^{-1} due to KTS and CaTS application with NPK through conventional (band placement) method. The increase in grain yield was significantly higher under all the KTS and CaTS treated plot over control. Maximum increase in grain yield (25.5%) was observed under the treatment 30 L KTS/ha + 30 L CaTS/ha + NPK (T_{12}) followed by T_{11}- NPK with 60 L KTS /ha (24.9%) and T_9- NPK with 30 L KTS/ha (23.5%) over alone application of NPK (T_8) through band placement. The higher yield from the combined application of CaTS and KTS with NPK in drip irrigation might be attributed, to enhanced nutrient uptake due to readily available for plant because it dissolves in soil-water solution and some amount held on clay particles in exchangeable form. Potassium enhanced the vegetative structure, source-to-sink strength and reproductive structure development, which leads to more conversion of photosynthates to grain resulted in higher yield. The findings are consistent with Maurya *et al.* (2014) [11]. Sulphur improved nutrient absorption and photosynthesis, at the same time strengthen the source-sink relation by accelerating the development of reproductive structures. The results are in line with the finding of Gahlout *et al.* (2010) [12], Thirupathi *et al.* (2017) [13, 16], Sinha *et al.* (1995) [14] and Pavithra *et al.* (2015) [15].

Stover and stone yield (kg ha^{-1})

In the present study (Table 3, fig. 1), stover yield (7951.3 kg ha^{-1}) and stone yield (1591.7 kg ha^{-1}) were significantly higher with application of NPK along with 30 L KTS/ha + 30 L CaTS through drip irrigation system and remained statistically at par with rest of the treatments except T_1- alone application of NPK (T_1) through drip irrigation 6931.0 and 1381.3 kg ha^{-1} and alone application of NPK (T_8) through band placement having 6703.8 and 1338.5 kg ha^{-1} stover and stone yield, respectively. This might be due to more vegetative growth, more plant height, a greater number of leaves per plant and dry matter production. Gnanasundari *et al.* (2019) [9], Thirupathi *et al.* (2017) [13, 16], Sarkar and Pal (2006) [17] and Thakur *et al.* (2001) [18] have supported these findings.

Harvest index (%): The harvest index (table 3, fig.1) did not differ significantly between treatments. When the application of NPK along with 30 L KTS/ha + 30 L CaTS/ha through drip irrigation system (T_7) recorded higher value of harvest index (48.7%) followed by T_4 & T_6 (48%), T_3 (47.5%), respectively and lower value (45.6%) was recorded under treatment of NPK without CaTS and KTS through band application. This was might be due to enhanced mobilization of photosynthates in to the reproductive parts (ears) of winter maize and which further increased grain yield and higher harvest index. Similarly, Yadav *et al.* (2014) [19] and Pavithra *et al.* (2015) [15] also concluded that more partitioning of assimilates toward sink by the application of K.

Effect of different treatments on economics

The economics of winter maize as manifested because of potassium and calcium thiosulphate, differentiated methods of fertilizers and irrigation application, labour requirement and above all the weather conditions prevailing during the crop period. The economics of maize production were calculated by itemising cultivation costs and subtracting them from the prices of various treatment costs to obtain the net return. Table 4 shows how the gross and net returns increased significantly when different levels of calcium and potassium thiosulphate were used. Highest gross return (Rs 184163 ha^{-1}), net return (Rs 124905 ha^{-1}) and B:C ratio (2.11), respectively of winter maize was recorded in treatment T_7 (NPK along with 30 L KTS/ha + 30 L CaTS/ha through drip irrigation system) among all treatments. It was due to cumulative resulted the higher grain, stover and stone yield, lead to more gross return, net return and B:C ratio. While, lowest gross return (Rs 139213 ha^{-1}), net return (Rs 79333 ha^{-1}) and B:C ratio (1.32), respectively was recorded under treatment T_8.

Correlation analysis

The correlation data (table 5) revealed that, all the yield attributing characters were higher positively correlated to each other. This shows that all growth attributing characters attributed to the yield production are correlated. However, harvest index showed very less correlation (0.529) with stover yield.

Table 2: Effect of various treatments on number of cobs plant^{-1}, weight of cobs plant^{-1}, weight of grains cob^{-1}, weight of stones cob^{-1} and 100 grains weight of winter maize.

Treatment	Number of cobs plant^{-1}	Weight of cobs plant^{-1}	Weight of grains cob^{-1}	Weight of stones/cob	100 grain weight (g)
T_1	1.0	116.1	89.9	18.6	27
T_2	1.0	134.9	108.0	20.50	29
T_3	1.0	143.1	116.5	20.9	31
T_4	1.0	144.6	117.9	20.8	31
T_5	1.0	132.8	106.6	20.8	29
T_6	1.0	139.1	112.4	20.7	30
T_7	1.0	150.1	121.6	21.3	32
T_8	1.0	111.5	86.4	18.1	26
T_9	1.0	137.7	111.1	20.5	30
T_{10}	1.0	134.2	107.9	20.6	29
T_{11}	1.0	139.3	112.6	20.7	30
T_{12}	1.0	141.6	115.0	20.9	31
S.Em	0.0	4.4	3.7	0.7	1.0
CD	NS	12.4	10.7	1.9	2.8

Table 3: Effect of various treatments on grain yield, stover yield, stone yield and harvest index of winter maize.

Treatment	Grain yield (kg/ha)	Stover yield (kg/ha)	Stone yield (kg/ha)	Harvest index (%)
T_1	7009.5	6931.0	1381.3	45.6
T_2	8146.0	7695.6	1538.4	46.8
T_3	8638.0	7798.6	1571.6	47.5
T_4	8728.8	7865.6	1587.7	48.0
T_5	8017.0	7868.3	1568.8	45.9
T_6	8396.0	7762.3	1561.9	48.0
T_7	9063.0	7951.3	1591.7	48.7
T_8	6729.5	6703.8	1338.5	45.6
T_9	8312.0	7807.5	1543.7	47.0
T_{10}	8104.0	7892.6	1548.5	46.2
T_{11}	8408.5	7836.3	1556.2	47.3
T_{12}	8546.0	7821.8	1578.2	47.6
S.Em	282.8	276.8	54.7	1.4
CD	813.6	796.3	155.6	NS

Table 4: Effect of various treatments on cost of cultivation, total gross return, net return and B:C ratio of winter maize.

Treatment	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	BC ratio
T_1	56127	144836	88709	1.58
T_2	57097	167223	110126	1.93
T_3	58067	176246	113800	2.04
T_4	60007	178060	118053	1.97
T_5	57327	165474	108146	1.89
T_6	58527	171867	117719	1.94
T_7	59257	184163	124905	2.11
T_8	59880	139213	79333	1.32
T_9	60610	170432	109822	1.81
T_{10}	62280	166992	104712	1.68
T_{11}	64970	172243	107273	1.65
T_{12}	63010	174706	111695	1.77
S.Em	0.0	4999.8	4999.8	0.08
CD	0.0	14224.6	14224.6	0.24

Table 5: Correlation of different yield attributing characters and yield of the maize

	Weight of cobs/plant(g)	Weight of grains/cob (g/cob)	Weight of stones/cob (g/cob)	100 grain weight (g)	Grain yield (kg/ha)	Stover yield (kg/ha)	Stone yield (kg/ha)
Weight of cobs/plant(g)	1						
Weight of grains/cob (g/cob)	0.999^{**}	1					
Weight of stones/cob (g/cob)	0.957^{**}	0.959^{**}	1				
100 grain weight (g)	0.985^{**}	0.984^{**}	0.916^{**}	1			
Grain yield (kg/ha)	1.000^{**}	0.999^{**}	0.957^{**}	0.985^{**}	1		
Stover yield (kg/ha)	0.921^{**}	0.926^{**}	0.986^{**}	0.866^{**}	0.921^{**}	1	
Stone yield (kg/ha)	0.953^{**}	0.958^{**}	0.995^{**}	0.911^{**}	0.953^{**}	0.986^{**}	1
Harvest index	0.809^{**}	0.798^{**}	0.632^{*}	0.866^{**}	0.809^{**}	0.529^{NS}	0.616^{*}

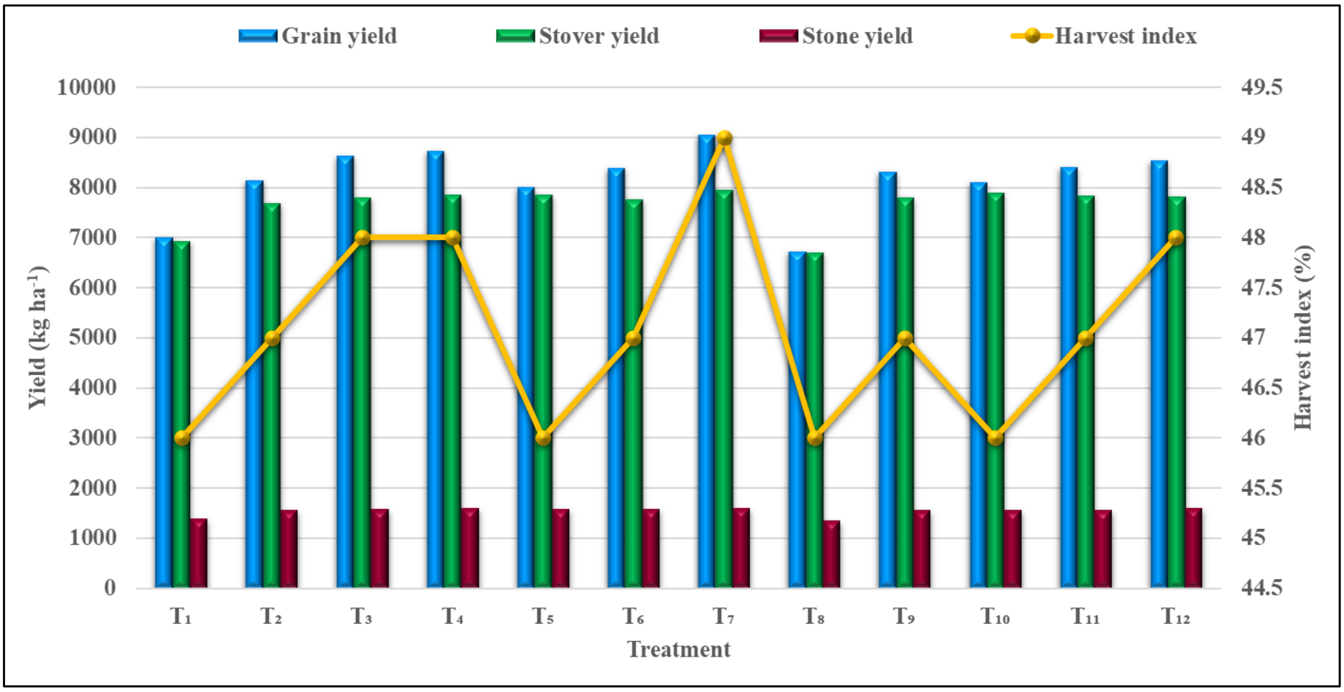

Fig 1: Effect of various treatments on grain yield, stover yield, stone yield and harvest index of winter maize

Conclusion

Experiment results showed that applying calcium and potassium thiosulphate increased yield, yield attributing character traits, and winter maize economics. Drip application of 150:75:38 N-P_2O_5-K_2O kg/ha along with 30 L CaTS/ha & 30 L KTS/ha (T_7) was found beneficial in terms of higher yield, yield components and economics of winter maize. Consequently, the use of calcium and potassium thiosulphate increased grain productivity and quality by sustaining soil health. Economic returns play a key role in persuading farmers to adopt any refined version of Agro-techniques. In the present research, gross and net returns, as well as a benefit: cost ratio, were observed to be significantly higher with the application of NPK along with calcium thiosulphate 30 L/ha and potassium thiosulphate 30 L/ha. Thus, the authors recommend using a proportionate combination of calcium and potassium thiosulphate to increase grain productivity and quality while maintaining soil health.

Future prospectus

Calcium and potassium thiosulphate is a new emerging chlorine-free, clear solution fertilizers. It has an excellent source of Ca, K and S liquid fertilizers. The advantage of thiosulfate fertilizers over other sulphur forms fertilizers is that the sulphur required for plant growth is available over a period of several weeks for plant growth and development resulted in higher grain production. So, long term trail should be conducted for precise conclusion.

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