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Assessment of potassium and sulphur on the soil properties, growth and yield of onion (*Allium cepa* L.)

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Abstract
The field experiment was conducted to study the effect of different levels of Sulphur and Potassium on the properties of the soil as well as on the growth and yield of Onion (*Allium cepa* L.) at the Research Farm of Soil Science, SHUATS, Prayagraj, India, during the winter season of 2020-21. Experimental layout was done in a Factorial Randomised Block Design (RBD) with 9 treatments which is replicated 3 times. Treatments consists of three levels of Potassium *i.e.* 0, 25 and 50 kg ha^{-1} and three levels of Sulphur *i.e.* 0, 15, 30 kg ha^{-1} where the treatments are assigned randomly. The results indicated that the maximum average plant height (64.02 cm), bulb length (4.99 cm), bulb diameter (6.99 cm), total bulb yield (13.72 q ha^{-1}) showed significantly better results with the treatment T_9 (Potassium at 50kg ha^{-1} and Sulphur at 30 kg ha^{-1}). The same treatment also showed better results in the physical properties of the post-harvest quality of the soil like increase in% pore space, decrease in bulk and particle density of the soil and also showed a gradual increase on the chemical properties of the soil like increase in pH, OC% and N, P, K, S values in the soil after harvest. Hence the results revealed that the treatment combination i.e. Potassium at 50 kg ha^{-1} and Sulphur at 30 kg ha^{-1} was found to be the most beneficial and significantly improved the growth parameters and bulb yield of onion grown under Prayagraj agromatic conditions.

Keywords: Growth parameters, onion, potassium, soil properties, sulphur, bulb yield

Introduction
Onion (*Allium cepa* L.), 2n=16, is an important species belonging to family *Alliaceae*. The genus Allium includes around 750 species out of which over 20 Allium species have been consumed by humans excluding the most important edible Alliums i.e. onion, Japanese onion, leak and garlic Van (1997) [27]. Onion is considered to be the second most important vegetable crop grown in the world next only to tomato. In India, Onion have been under cultivation for the last 5000 years. The Onion plant have hollow leaves and shallow roots. In the world, India stands first in area and ranks second in production after China. The total area under onion during 2013-14 was 12.03 lakh hectare with a production of 194.01 lakh tonne and productivity of 16.1 t ha^{-1}. Maharashtra is the leading state in Onion production followed by Uttar Pradesh and Orissa Anon, (2010) [5]. It is grown all over the country across various states like Maharashtra, Gujarat, Uttar Pradesh, Orissa, Karnataka, Andhra Pradesh, Madhya Pradesh and Bihar which are the major onion growing states in the country. It is cultivated over an area of 1064 thousand tons but the productivity in India is very low *i.e.* 14.21 tons ha^{-1}. Potassium plays an important role on Onion production. Generally, a heavy dose of Potassium is recommended for Onion cultivation. Like other tuber and roots crops Onion is very important to Potash. Due to its role in storage quality, bulb size, translocation of photosynthesis and yield per plant Potassium is considered to be one of the most important element required for high production of Onion. Potassium deficiency in Onion is expressed by the appearance of brown tips in older leaves and poor bulb formation. The application of an appropriate quantity and source of K to Onion at critical growth stages is thus essential for maintenance of growth and quality Brar (2002) [9]. The application of sulphur has been found not only to increase the bulb yield of onion but also improve its quality, especially pungency and flavours. The yield potential of onion has not been exploited fully as the sulphur fertilizer is used in very low quantity instead of its very high requirement. In recent years, sulphur is receiving more attention throughout the world. The deficiency of sulphur in the soil, as a nutrient is increasing in India. Surveys have found that 240 districts to be generally deficient in S and the problem is spreading Sakal *et al*., (2001) [21]. A recent effort by the Fertilizer Association of India,

The Sulphur Institute and the International Fertilizer Industry Association (FAI-TSI-IFA) studied 27,000 samples distributed over 12 states and found that over 40% of samples were deficient in available S and another 35% potentially deficient. More than 70% soil samples taken from Uttar Pradesh, Madhya Pradesh, Maharashtra, Orissa, Jharkhand, West Bengal, Andhra Pradesh and Karnataka were low to medium in available Sulphur Biswas *et al.,* (2004) [8].. The main reason behind such widespread deficiency are over dependence on "S-free" fertilizers, depletion of S without continuous cropping, sizable areas (around 27% of the country's grossed cropped area) under pulses and oilseeds that have higher requirement for S, loss of S due to leaching, soil erosion, lack of organic manure addition and low awareness of farmers towards use of importance of S in agriculture. Therefore, with these facts in consideration, the present study was carried out to find the effect of potassium and sulphur on the soil properties, response of onion to the bulb yield and plant growth properties and also the economic benefits and profit.

Materials and Methods

The field experiment to study the effect of Potassium and Sulphur on Onion (*Allium cepa* L.) was conducted at Research Farm of Soil Science, SHUATS, Prayagraj, India. Improved variety of Onion Nasik Red was selected for study. Two different factors were considered: (A) Potassium levels (0, 50, and 100) kg ha^{-1}. (B) Sulphur levels (0, 15, and 30) kg ha^{-1}. The experiment consists of 9 treatments and the field was laid out in a Factorial Randomized Block Design with three replications and treatments were assigned accordingly. Size of each plot was 2m x 1m. The seedlings were transplanted into the plots at a spacing of 20cm x 15cm. Standard recommended doses of Nitrogen as Urea and Phosphorus as DAP (Diammonium Phosphate) were applied across all plots at 100 kg ha^{-1} and 50 kg ha^{-1} respectively. Potassium was applied as MOP (Muriate of Potash) and Sulphur was applied in the form of elemental sulphur according to the treatment combinations which then applied as a basal dose before transplanting of Onion seedlings while Nitrogen was applied at split doses, first after transplanting and the second dose after 30 days of transplanting. Various intercultural operations such as irrigation, weeding, pest control etc. were done uniformly as required. Data from the plants were recorded and observed by selecting and tagging 3 plants at random for each treatment and plant height was observed at 30, 60 and 90 days after transplanting (DAT). Bulb height, width and total yield per plot were recorded from each individual plot both before transplanting operations and also after harvest by taking soil at depth of 0-15 cm. The various parameters analysed were pH, organic carbon%, pore- space%, and bulk and particle density, E.C, Nitrogen, Phosphorus, Potassium and Sulphur.

Table 1: Initial status of the soil before transplanting of Onion

Particulars	Scientists (Year)	Methods	Unit	Results
Physical Properties				
Bulk density	Methuval *et al.,* (1992) [17]	Graduated Measuring Cylinder	Mg m^{-3}	1.30
Particle density	Methuval *et al.,* (1992) [17]	Graduated Measuring Cylinder	Mg m^{-3}	2.5
Pore space	Methuval *et al.,* (1992) [17]	Graduated Measuring Cylinder	(%)	51.3
Water Holding capacity	Methuval *et al.,* (1992) [17]	Graduated Measuring Cylinder	(%)	48.13
Soil Colour	Munsell, (1971) [3]	Munsell colour chart	Colour	Dry- Light yellow Wet- Olive Brown
Soil Texture	Bouyoucos, (1927) [10]	Bouyoucos Hydrometer	Sand, Silt, Clay (%)	Sandy Loam 55, 25, 20
Chemical Properties				
Soil pH	M. L. Jackson, (1958) [14]	pH meter	-	7.4
EC	Wilcox, (1950) [29]	Digital Conductivity meter	dS m^{-1}	0.2
OC	Walkley and Black, (1947) [28]	Walkley and Black wet oxidation method	Kg ha^{-1}	0.42
Nitrogen	Subbiah and Asija, (1956) [24]	Modified Akaline permanganate oxidation method	Kg ha^{-1}	253.72
Phosphorus	Olsen *et al*., (1954) [18]	Spectrophotometric method	Kg ha^{-1}	23.6
Potassium	Toth and Prince, (1949) [26]	Flame photometric method	Kg ha^{-1}	216.2
Sulphur	Chesnin and Yien, (1950) [11]	Tubidimetric method	Kg ha^{-1}	22.60

Results and Discussion

As illustrated in table 1 shows the pre-transplant soil data and table 2 and 3 shows the analysed statistical data of the various effects of Potassium and Sulphur doses on the soil properties, growth and yield parameters of Onion of which the results are discussed below. At the stages of the growth of the plant, the treatment combination T_9 (K at 50 kg ha^{-1} and S at 30 kg ha^{-1}), recorded the maximum plant height at 39.58cm, 55.35 cm and 64.02 cm at 30, 60 and 90 DAT respectively, while control treatment recorded the lowest plant height at 28.50 cm, 37.81 cm and 46.00 cm at 30, 60 and 90 DAT respectively. The bulb length and diameter of the bulbs showed significant increase with higher levels of Potassium and Sulphur. The treatment combination T_9 (K at 500 kg ha^{-1} and S at 30 kg ha^{-1}) gave the highest results at 4.99 cm and 8.89 cm for bulb length and diameter respectively. The treatment combination T_9 (K at 100 kg ha^{-1} and S at 30 kg ha^{-1}) has the highest total bulb yield. The application of Potassium plays an important role in the metabolism and many processes to sustain and promote plant vegetative growth and development and also plays a major role in cell division and elongation and metabolism and synthesis of carbohydrates and protein compounds. The increase in plant height due to increasing levels of Potassium were also observed and recorded by Abou El-Nasr and Ibrahim (2011) [2], Shafeek *et al.,* (2013) [23] and Behairy *et al.,* (2015) [6]. Higher dosage of sulphur also showed significant increase in plant height across all stages of crop growth. The increase in plant might be due to the role of Sulphur in the synthesis of chloroplast Rashid (2010) [20], Meher *et al.,* (2016) [16] and Tripathy *et al.,* (2013) [25] also reported similar results of increase in plant height of Onion with increasing levels of Sulphur. Sulphur application also plays an important role in determining the shape and size of Onion bulb. More efficient S utilization resulted in greater

increases in bulb length Abbey *et al.,* (2002) [1]. Potassium application at higher doses showed significant increase in total yield of Onion. Similar results were observed by Shah *et al.,* (2013) [22]. Sulphur increases the uptake of N, P, K and S by the plant which might lead to enhanced synthesis and translocation of photosynthesis to the bulbs and hence increase the overall total yield. Similar results on the total yield of Onion due to increasing levels of Sulphur were also observed by Meher *et al*., (2016) [16].

The bulk density (1.25 Mg m^{-3}) and particle density (2.88 Mg m^{-3}) of the soil after crop harvest decreased as a result of increased dosage of Potassium and Sulphur which might be due to the fact that Onion is a bulb crop and it loosens the soil when it grows in the soil thereby improving the soil structure and increasing the availability of certain plant nutrients in soil, which in turn showed an increase in pore space percentage to the soil data before transplanting. These results were also reported by Pradhan *et al.,* (2014) [19]. The organic carbon% in the soil showed slight decrease with increasing dosage of Potassium and Sulphur which might be attributed to the fact that plants used the organic carbon present for their growth and development and also because more inorganic materials were added rather than organic fertilizers and due to lack of the addition of FYM. This was also reported by Basavaraja *et al.,* (2007) [7]. The soil pH showed a significant increase after crop harvest with increasing dosage of Potassium and Sulphur. The initial pH value of the soil before transplanting operations was observed to be at 7.4 and the application of K at 100 kg ha^{-1} and S at 30 kg ha^{-1} showed pH can be due to the fact that with higher application of Potassium and Sulphur, it increases the overall metabolism of the plant photosynthesis and respiration. Respiration in plants changes the carbon dioxide and reacts with water to form carbonic acid in the soil. This was also reported by Pradhan *et al.,* (2014) [19]. The EC dS m^{-1}value of the soil did show a slight increase after harvest and the results were found to be significant and the addition of different levels of Potassium and Sulphur showed a particular effect. The available values of NPK along with Sulphur in the soil after harvesting showed a significant increase with increasing dosage on Potassium and Sulphur. Nitrogen levels were highest in the treatment combination T_9 (K at 50 kg ha^{-1} and lowest in control at 214.74 kg ha^{-1}.

Table 2: Effect of different levels of Potassium and Sulphur on the soil properties (physical and chemical) after harvesting of Onion.

Treatment	Bulk density (Mg m^{-3})	Particle density (Mg m^{-3})	Pore space (%)	OC (%)	pH (1:2)	EC (d s m^{-1})	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	S (kg ha^{-1})
T_1	1.25	2.58	51.82	0.53	7.87	0.43	214.74	31.20	195.50	17.13
T_2	1.19	2.73	53.37	0.56	7.61	0.37	221.21	35.78	201.00	19.60
T_3	1.15	2.81	53.86	0.58	7.79	0.41	222.49	36.26	202.50	21.17
T_4	1.23	2.73	52.83	0.51	7.77	0.37	226.37	37.24	204.97	22.13
T_5	1.18	2.69	53.91	0.58	7.78	0.38	227.21	38.95	205.37	23.40
T_6	1.13	2.85	54.75	0.62	7.60	0.38	232.63	43.17	210.33	28.50
T_7	1.20	2.75	52.60	0.52	7.58	0.41	229.25	40.18	207.40	25.53
T_8	1.16	2.79	52.17	0.61	7.56	0.39	231.56	41.43	208.97	26.97
T_9	1.12	2.88	57.13	0.64	7.60	0.36	235.00	45.17	212.33	29.43
S.Em. (±)	0.405	0.217	0.370	0.005	0.029	0.008	0.427	0.364	0.405	0.423
C. D @5%	0.773	0.460	0.783	0.011	0.061	0.018	0.905	0.773	0.859	0.898

Table 3: Plant height (cm) of onion

Treatments	30 DAT	60 DAT	90 DAT
T_1 – Control	28.50	37.81	46.00
T_2 - 15 kg S ha^{-1}	33.92	46.95	57.50
T_3 - 30 kg S ha^{-1}	39.25	52.85	59.88
T_4 – 25 kg K_2O ha^{-1}	29.83	41.22	54.50
T_5 - 25 kg K_2O ha^{-1} + 15 kg S ha^{-1}	36.83	48.68	59.25
T_6 - 25 kg K_2O ha^{-1} + 30 kg S ha^{-1}	39.33	53.88	62.20
T_7 - 50 kg K_2O ha^{-1}	31.58	45.04	56.42
T_8 - 50 kg K_2O ha^{-1} + 15 kg S ha^{-1}	38.58	51.88	59.75
T_9 - 50 kg K_2O ha^{-1} + 30 kg S ha^{-1}	39.58	53.35	64.02
S.Em. (±)	0.655	0.545	0.626
C. D @5%	1.388	1.154	1.328

Table 4: Number of leaves per plant of onion

Treatments	30 DAT	60 DAT	90 DAT
T_1 – Control	6.42	10.15	13.50
T_2 - 15 kg S ha^{-1}	6.75	10.70	15.75
T_3 - 30 kg S ha^{-1}	7.33	11.68	17.38
T_4 - 25 kg K_2O ha^{-1}	6.58	10.64	15.42
T_5 - 25 kg K_2O ha^{-1} + 15 kg S ha^{-1}	6.92	10.93	15.75
T_6 - 25 kg K_2O ha^{-1} + 30 kg S ha^{-1}	7.33	12.65	18.37
T_7 - 50 kg K_2O ha^{-1}	6.67	10.63	15.67
T_8 - 50 kg K_2O ha^{-1} + 15 kg S ha^{-1}	7.08	11.46	17.00
T_9 - 50 kg K_2O ha^{-1} + 30 kg S ha^{-1}	7.75	13.77	19.52
S. Em. (±)	0.239	0.208	0.224
C. D @5%	0.507	0.441	0.475

Table 5: Effect of different levels of Potassium and Sulphur on the Yield (t ha^{-1}) of Onion

Treatments	Bulb width (cm)	Bulb length (cm)	Bulb yield (t ha^{-1})
T_1 – Control	4.69	4.10	6.58
T_2 - 15 kg S ha^{-1}	5.39	4.67	8.02
T_3 - 30 kg S ha^{-1}	6.39	4.99	9.08
T_4 - 25 kg K_2O ha^{-1}	5.19	4.50	7.83
T_5 - 25 kg K_2O ha^{-1} + 15 kg S ha^{-1}	5.99	4.88	8.66
T_6 - 25 kg K_2O ha^{-1} + 30 kg S ha^{-1}	6.99	5.56	9.23
T_7 - 50 kg K_2O ha^{-1}	5.39	4.61	8.32
T_8 - 50 kg K_2O ha^{-1} + 15 kg S ha^{-1}	7.69	5.68	10.28
T_9 - 50 kg K_2O ha^{-1} + 30 kg S ha^{-1}	8.89	6.27	13.72
S. Em. (±)	0.282	0.157	0.364
C. D @5%	0.597	0.334	0.773

Conclusion

Based on this study, it is concluded that, the present paper highlights the positive effect of Potassium and Sulphur on the growth, yield and soil properties of growing Onion. Combined application of 50 kg K_2O ha^{-1}, 30 kg S ha^{-1},100 kg ha^{-1} Urea and 50 kg ha^{-1} DAP is an optimum nutrient for enhancing growth, increasing bulb size and yield attributes and probability of Onion as compared to other treatment combinations.

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