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EFFECT OF SULPHUR AND ZINC UNDER VARYING MOISTURE REGIMES ON NUTRIENT USE EFFICIENCY AND YIELD OF CABBAGE (*BRASSICA OLERACEA VAR. CAPITATA* L)

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ABSTRACT

To evaluate effects of sulphur and zinc under varying soil moisture regimes on yield of cabbage and on nutrient use efficiency of S and Zn, an experiment was conducted in completely randomized design with a factorial arrangement of treatments with three replications. The result showed that increasing levels of sulphur and zinc under 1.0 IW/CPE moisture regime brought substantial improvement in yield, sulphur and zinc content in head, available sulphur and zinc and nutrient use efficiency. The application of sulphur @ 30 kg/ha, zinc 3 kg/ha and irrigation at 1.0 IW/CPE ratio significantly increased yield 0.727, 0.720 and 0.795kg per plant and water expense efficiency 288.15, 286.23 and 245.91 kg/ha/cm, respectively. Thus, application of sulphur 30 kg/ha, zinc 3 kg/ha and irrigation at 1.0 IW/CPE ratio is recommended for higher cabbage production with better nutrient use and water expense efficiency.

INTRODUCTION

Botanically, cabbage is known as *Brassica oleracea* var. *capitata* belongs to the family cruciferae. It is rich in vitamins and minerals including phosphorus (44 mg), potassium (114 mg), calcium (39 mg), sodium (14.1 mg) and iron (0.8 mg) (Fageria *et al.,* 2003). It is well documented that sulphur and zinc are the essential plant nutrient and plays a vital role in biosynthesis of certain amino acids and enzymes. Availability of zinc might have stimulated the metabolic and enzymatic activities thereby increasing the plant growth parameters (Kasturikrishana and Ahlawat, 2003). Zinc is becoming the most important nutritional factor, limiting the yield of various crops especially in light textured soils. Similarly, optimum sulphur fertilization helps plants to grow and develop properly and improves utilisation of other nutrients (Choudhary *et al.*, 2014). Soil moisture also plays an important role in the extractability of nutrients. Changes in soil moisture content can regulate the nutrients' availability and plant species' distribution by changing soil solution chemistry (Misra and Tyler, 1999). Scheduling of water supply at the most critical growth stages would boost the crop production efficiency on one hand and water economy on other hand (Adam and Anderson, 1983). Recovery of applied nutrients is mainly governed by available soil moisture. Therefore, it has become necessary to search for an approach wherein efficiency of fertilizer nutrient could be increased by optimum application of nutrients particularly sulphur and zinc at proper water regimes. Considering the above facts, the present investigation was undertaken.

MATERIALS AND METHODS

The experiment comprised 18 treatment combinations including three levels of sulphur (0, 30 & 60 kg/ha), three levels of zinc (0, 3 & 6 kg/ha) and two levels of moisture regime (0.5 & 1.0 IW/CPE ratio). The experiment was laid out in randomized block design with three replications. The experimental field was sandy loam with slight alkaline having pH 8.2, low in organic carbon (0.17%), low in available nitrogen (141 kg ha^{-1}), phosphorus (17 kg ha^{-1}), zinc (0.41 mg kg^{-1} soil) and sulphur (6.98 mg kg^{-1} soil) and medium in potassium (152 kg ha^{-1}) contents. Five plants were tagged randomly in each plot to record observation on the yield, sulphur and zinc content in head. Sulphur content in head was estimated by turbidometric method (Tabutabi and Bermner, 1970). Zinc content was assessed by the analysis of suitable aliquat of digest–II with atomic absorption spectrophotometer "Varian Techron AAS 120" (Lindsay and Norwell, 1978), Available sulphur in soil by extraction of heated sample with 1% NaCl followed by turbidometric method (Willium and Steinberg, 1959).

The nutrient (S/Zn) use efficiency was calculated as a ratio of economic yield from treated plots minus economic yield from control plot to the dose of nutrient (S/Zn).

$$\text{Nutrient(S / Zn) use efficiency(kg head kg}^{-1}\text{nutrient)} = \frac{Yt - Yc}{Ft}$$

Where,

Yt = Head yield in treated plot (kg ha^{-1})

Yc = Head yield in control plot (kg ha^{-1})

Ft = Dose of fertilizer/nutrient applied (kg ha^{-1})

However; the water expense efficiency (WEE) of crop is the ratio between the produce (head yield) and the water applied in obtaining that produce and computed by the following formula

$$\text{WEE (kg head ha}^{-1}\text{cm}^{-1}) = \frac{\text{Yield(kg ha}^{-1})}{\text{Total water expence(cm)}}$$

Total water expense of the crop was computed as the sum of irrigation water, rainfall during the crop growing season and profile water depletion (difference in soil water storage of 100 cm profile at the time of transplanting to harvest stage). The total soil water storage in 100 cm soil profile was calculated by following formula (Parihar *et al.,* 1976).

$$\text{Total soil water storage(cm m}^{-1}) = \frac{\sum_{i}^{n} = 1\ \text{Water content in ith layer(\%)} \times \text{Depth of ith layer(cm)} \times \text{B.D of layer (Mg m}^{-3})}{100}$$

To test the significance of variation in data obtained from various characters, the technique of analysis of variance was adopted assuggested by Fisher (1950) for randomized block design.

RESULTS AND DISCUSSION

The application of increasing levels of sulphur 60 kg ha^{-1} and zinc 6 kg ha^{-1} significantly increased the yield per plant under moisture regime 1.0 IW/CPE ratio (Table 1), however, sulphur 30 and zinc 3 kg ha^{-1}, respectively were found statistically at par to it. The increase in yield might be due to the role of sulphur by lowering the pH of saline-alkaline soil resulting in increased availability of many nutrients (Hossan and Olsen, 1966). The soil application of zinc resulted in increased supply of the available zinc to the plants which led proper growth and development because directly or indirectly zinc regulates the various physiological processes of plants (Marschner, 1995). These results are in close conformity with those of Singh *et al*. (2012).

Yield of cabbage was recorded 0.795 kg per plant under moisture regime 1.0 IW/CPE ratio which was 44.28 per cent higher than 0.5 IW/CPE ratio (Table-1). The increase in yield under increased irrigation frequency might be due to better photosynthesis and translocation of assimilates towards reproductive structures owing to increased supply of moisture (Ughade and Mahadkari, 2015). The sufficient moisture during head development of cabbage might have also increased mobilization of mineral nutrients including sulphur and zinc to reproductive parts which ultimately increased the head yield. These results are in close conformity with those of Kasturikrishana and Ahlawat (2003).

The sulphur and zinc content in head increased significantly with the increasing levels of sulphur and zinc (Table 1). The initial available zinc status of the experimental soil was below the critical limits *i.e.* 0.5 ppm DTPA zinc. Thus, the application of sulphur and zinc in soil increased the availability of sulphur and zinc in the rhizosphere which was 6.98 to 12.06 mg/kg S and 9.70 to 10.83 mg/kg Zn, respectively. The sulphur and zinc increased the cation exchange capacity (CEC) of roots might also helped more absorption of nutrients from the soil, ultimately yield and nutrient content in head (Romheld and Marscher, 1991). These results are in conformity with the findings of Choudhary *et al*., (2014).

Maximum sulphur use efficiency 330.86 kg head per kg sulphur was recorded under sulphur 30 kg ha^{-1}. Similarly the maximum zinc use efficiency 3209.88 kg head per kg Zn was recorded under treatment 3 kg Zn ha^{-1} (Table 2). The increase of the Zn use efficiency with Zn application levels might be attributed to the release of Zn from Zn mineral and the increase of microorganism activities in constant moisture incubation conditions that might have led to higher organic bounded Zn and its availability (Haldar and Mandal, 1979).

The water expense efficiency was recorded significantly higher

Table 1: Effect of sulphur and zinc fertilization under varying moisture regimes on yield of cabbage, sulphur and zinc content in head

Treatment	Yield per plant(kg)	Sulphur content(%)	Zinc content(ppm)
Sulphur levels			
S (0 kg ha^{-1})	0.526	1.04	11.86
S (30 kg ha^{-1})	0.727	1.20	13.71
S (60 kg ha^{-1})	0.767	1.24	14.25
SEm ±	0.018	0.02	0.30
CD (p=0.05)	0.052	0.06	0.87
Zn levels			
Zn (0 kg ha^{-1})	0.527	1.09	11.20
Zn (3 kg ha^{-1})	0.720	1.16	13.92
Zn (6 kg ha^{-1})	0.771	1.23	14.70
SEm ±	0.018	0.02	0.30
CD (p=0.05)	0.052	0.06	0.87
Moisture regimes (IW/CPE)			
I_1 (0.5)	0.551	1.13	11.49
I_2 (1.0)	0.795	1.19	15.06
SEm ±	0.015	0.02	0.25
CD (p=0.05)	0.042	0.05	0.71

S = Sulphur, Zn = Zinc & I = Moisture regime

Table 2: Effect of sulphur and zinc fertilization under varying moisture regimes on available sulphur and zinc content in soil, nutrient use efficiency and water expense efficiency (WEE)

Treatment	Available nutrient content at harvest (mg kg^{-1})		Nutrient use efficiency (kg head kg^{-1} S/Z)		WEE(kg ha^{-1}cm^{-1})
	S	Zn	S	Zn	
Sulphur levels					
S (0 kg ha^{-1})	6.98	0.41	-	2038.17	208.53
S (30 kg ha^{-1})	11.66	0.46	330.86	2551.45	288.15
S (60 kg ha^{-1})	12.06	0.47	198.35	2972.00	304.07
SEm ±	0.23	0.01	9.77	161.34	7.13
CD (p=0.05)	0.67	0.03	29.64	489.37	20.49
Zn levels					
Zn (0 kg ha^{-1})	9.70	0.40	207.10	-	208.86
Zn (3 kg ha^{-1})	10.17	0.46	283.73	3209.88	286.23
Zn (6 kg ha^{-1})	10.83	0.48	302.99	1831.20	305.65
SEm ±	0.23	0.01	9.77	161.34	7.13
CD (p=0.05)	0.67	0.03	29.64	489.37	20.49
Moisture regimes (IW/CPE)					
I_1 (0.5)	9.95	0.38	216.80	2137.64	287.92
I_2 (1.0)	10.51	0.52	312.42	2903.44	245.91
SEm ±	0.19	0.01	7.98	131.73	5.82
CD (p=0.05)	0.54	0.02	24.20	399.57	16.73

S = Sulphur, Zn = Zinc & I = Moisture regime

under sulphur 60 kg ha^{-1} followed by sulphur 30 kg ha^{-1}. Similarly, significantly higher water expense efficiency of 286.23 and 305.65 kg ha^{-1} cm^{-1} was also recorded under 3 kg Zn ha^{-1} and 6 kg Zn ha^{-1}. The increase in WEE was due to increasing levels of sulphur and zinc. Parihar (1994) also reviewed that heavy dose of fertilizer may cause accelerated depletion of profile stored water and leaving little water for crop use towards maturity, as the fertilized crop develop better root proliferation which extracted more water from the soil. The water expense efficiency was significantly affected by higher moisture regimes (Table 2). The WEE declined with successive increase in number of irrigations due to greater expense of water by evapo-transpiration without proportionate increase in head yield. Frequent irrigation though, necessary for yield maximization usually have lowered the WEE because moisture or wet surface of soils results in increased loss of soil moisture through evaporation. These findings also substantiated by the findings of Patel *et al*., (2013) and Kasturikrishana and Ahlawat (2003).

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