Introduction

Maize is one of the most important cereal crop next to rice, wheat and jowar in respect of area and production in India. Maize cultivated over an area of 9.3 million hectares with production of 24.2 million tonnes and average yield of 2602 kg/ha in the country (FAO STAT, 2014). Gujarat occupies an area of 5.59 lakh hectares, with production of 7.86 lakh tonnes and productivity of 1953 kg /ha (DOA, 2013). According to the character of the kernels, it is classified in various groups among which “popcorn” is major one. Popcorn (Zea mays L. var. everta Sturt) also known as popping corn is popular and nutritious snack food in many parts of World. All parts of corn such as grain, branches and leaves, even corn cob and corn silk is used numerously in human nutrition, fed livestock and poultry and pharmaceutical industry. The kernels of teosinte are readily “popped” for human consumption like modern popcorn. It has tremendous potentially because, it gives more remuneration to the farmer. Potassium and sulphur play a vital role in the nutrition of plants. Fertility analysis of Indian soils has indicated that the soils are deficient in sulphur and medium to low in the potash. In fact, these nutrients are lacking mostly in the soils of Saurashtra region. Therefore, application of chemical fertilizers becomes essential to raise the crop yield. Potassium is an essential
element for plant growth and development and is the most abundant cation in plants, making up 3-5% of a plant's total dry weight. Sulphur plays an important role in enhancing the productivity of popcorn crop.

**Materials and Methods**

The experiment was conducted during rabi season 2013-14 in D-5 plot of Instructional Farm at Krushigadh, College of Agriculture, Junagadh Agricultural University, Junagadh. It is Geographically Junagadh is situated at 21.5° N latitude and 70.5° E longitude with an altitude of 60 m above the mean sea level. The experiments were laid out in Factorial Randomized Block Design having 16 treatments with three replications. The gross and net plot sizes were 5.0 m X 3.6 m and 4.2 m X 2.4 m, respectively. The experiment consisted of 4 levels of potassium (0, 30, 60 and 90 kg K₂O ha⁻¹) and 4 levels of sulphur (0, 20, 40, 60 kg S ha⁻¹). The soil of the experimental field was medium black calcareous soil with pH 7.9 and EC 0.35 dS m⁻¹. The crop was fertilized with potassium and sulphur as per treatment allotted to each plot in the form of MOP and Cosavet fertis. WG. (90%) in basal application and nitrogen and phosphorus in the form of urea, dammonium phosphate in the furrows, respectively 1/3rd nitrogen applied before sowing, 1/3rd at 20 days after sowing and remaining 1/3rd at 40 days after sowing, and phosphorus applied as basal. Amber popcorn variety was used as planting material in this study. The seeds were dibbled at a spacing of 60 cm x 20 cm using a seed rate of 15 kg ha⁻¹ during the last week of November.

Five plants were selected at random from each plot to record dry matter production per plant and yield parameters, seed yield and fodder yield (kg ha⁻¹) by using standard procedure. Similarly for grain yield, cobs of each plot after removing were shelled with the help of machine sheller and were weighed to have grain yield per plot. All other recommended agronomic practices and plant protection measures were carried out to all treatments uniformly during the course of study.

**Results and Discussion**

**Effect of Potassium**

**Dry matter yield**

The dry weight of leaves, shoot, root and total plant were significantly recorded higher with 60 kg K₂O ha⁻¹ (K₃) at 30, 60 DAS and leaves, shoot, root and total plant at harvest (Table 1). The leaves were remain at par with 90 kg K₂O ha⁻¹ (K₄) at 30, 60 DAS and 30 kg K₂O ha⁻¹ (K₂) and 90 kg K₂O ha⁻¹ (K₄) at harvest. Shoot was remain at par with 30 kg K₂O ha⁻¹ (K₂) and 90 kg K₂O ha⁻¹ (K₄) at 30 DAS and at harvest, the root was remain at par with 90 kg K₂O ha⁻¹ (K₄) at harvest, seed was at par with 30 kg K₂O ha⁻¹ (K₂) and 90 kg K₂O ha⁻¹ (K₄) at harvest, while total plant was at par with 90 kg K₂O ha⁻¹ (K₄) at 30 DAS and harvest.

The application of potassium was found to increase the shoot dry weight of maize which may be due to selective and adequate potassium uptake in plant tissue (Kaya et al., 2009). The adverse effect of ammonium on root growth in Arabidopsis in absence of potassium (Cao et al., 1993) and this harmful effect can be alleviated by potassium supply which activates the enzymes involved in ammonium assimilation (Hagin et al., 1990) through which root dry weight increased in maize crop. Tacket and Pearson (1964) reported that potassium doubles the weight of roots at harvest.
It can be attributed to high capability of photosynthesis by increasing the capturing carbon and enzyme rubisco and encouraging synthesis and matter transport in developing plant which helps to increase the dry weight of leaves, shoot, root and total dry weight with potassium levels. These results are already in agreement with those reported by Kalpana and Krishnarajan (2002) and Maurya et al., (2004)) for total dry matter, Bhatt and Jain (2012), Aslam et al., (2013) for shoot dry weight.

**Yield attributes**

An examination of data (Table 2) showed that different levels of potassium exhibited their significant influence on yield attributes. Application of 60 kg K$_2$O ha$^{-1}$ (K$_3$) recorded significantly the higher cob girth (15.67 cm), cob length (18.61 cm), number of cobs per plant (1.47), number of grains per cob (250.41), grain rows per cob (14.83), 100 seed weight (23.11 g), seed weight per cob (57.97 g), dry weight of cob (32.0 g), whereas the lowest was observed with K$_1$ (control).

Potassium is essential for many physiological processes such as photosynthesis and formation of ferredoxin which functions as electron transporter in photosynthesis (Zehler et al., 1981), translocation of photosynthates into sink, activation of enzymes and it increases the NUE increase the metabolites and nutrients to develop reproductive structures (Brar et al.,2012) seems to have resulted in increased cob girth, cob length, number of cobs, number of grains per cob, grain rows per cob, 100 grain weight and seed weight. The findings are close agreement with those obtained by Tariq et al., (2011) and Chaudari (2012).

**Effect of sulphur**

**Dry matter yield**

The dry weight of leaves, shoot, root and total plant were significantly recorded higher with S$_3$ (40 kg S ha$^{-1}$) at 30, 60 DAS and leaves, shoot, root, seed and total plant at harvest (Table 1; Figs. 1 and 2). The leaves were remain at par with S$_4$ (60 kg S ha$^{-1}$) at 30, 60 DAS and at harvest, shoot was remain at par with S$_4$ (60 kg S ha$^{-1}$) at 30DAS and at harvest, root and seed was at par with S$_4$ (60 kg S ha$^{-1}$) at harvest, while total plant at par with S$_4$ (60 kg S ha$^{-1}$) at 30 DAS.
Table 1 Effect of potassium and sulphur on dry matter yield of popcorn at 30 DAS, 60DAS and at Harvest

<table>
<thead>
<tr>
<th>Treatments</th>
<th>30DAS</th>
<th>60DAS</th>
<th>Harvest</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Leaves</td>
<td>Shoot</td>
<td>Root</td>
</tr>
<tr>
<td>Potassium levels (kg K₂O ha⁻¹)</td>
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<tr>
<td>K₀</td>
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<tr>
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<td>1.28</td>
<td>0.18</td>
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<tr>
<td>Sulphur levels (kg S ha⁻¹)</td>
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<tr>
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<tr>
<td>S₀-40</td>
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<td>S₀-60</td>
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<td>0.18</td>
</tr>
<tr>
<td>C.Em. +</td>
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<td>0.89</td>
<td>0.12</td>
</tr>
<tr>
<td>C.D. (P=0.05)</td>
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Table 2 Effect of potassium and sulphur on yield and yield attributes of popcorn

<table>
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<tr>
<th>Treatments</th>
<th>Cob girth (cm)</th>
<th>Cob length (cm)</th>
<th>Number of cobs per plant</th>
<th>Number of grains per cob</th>
<th>Grain rows per cob</th>
<th>100 seed weight (g)</th>
<th>Seed weight per cob (g)</th>
<th>Dry weight of cob (g)</th>
<th>Seed yield (kg/ha)</th>
<th>Fodder yield (kg/ha)</th>
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<tr>
<td>K₀</td>
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<td>14.58</td>
<td>1.16</td>
<td>236.18</td>
<td>12.58</td>
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<td>0.44</td>
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<td>1.28</td>
<td>0.84</td>
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<td>233.1</td>
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<tr>
<td>C.Em. +</td>
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<td>0.12</td>
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<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
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</tr>
</tbody>
</table>

KₓS Interaction
| S.Em. + | 0.86 | 0.97 | 0.09 | 5.83 | 0.87 | 0.85 | 2.57 | 1.67 | 168.1 | 466.3 |
| C.D. (P=0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| C.V.% | 10.38 | 10.02 | 11.22 | 4.14 | 10.82 | 7.00 | 8.71 | 11.14 | 8.56 | 14.29 |
Fig. 1 Dry weight of leaves, shoot, root and seed (g plant⁻¹) within plant at different growth stages under different potassium levels

- **30 kg K₂O ha⁻¹**
- **60 kg K₂O ha⁻¹**
- **90 kg K₂O ha⁻¹**
**Fig. 2** Dry weight of leaves, shoot, root and seed (g plant$^{-1}$) within plant at different growth stages under different sulphur levels

**20 kg S ha$^{-1}$**

- **30 DAS**
  - Root: 2.29
  - Leaves: 4.2
  - Shoot: 23.83

- **60 DAS**
  - Root: 9.5
  - Leaves: 19.83
  - Shoot: 31.89

- **Harvest**
  - Seed: 57.38
  - Root: 15.19
  - Shoot: 43.58

**40 kg S ha$^{-1}$**

- **30 DAS**
  - Root: 2.69
  - Leaves: 4.41
  - Shoot: 25.17

- **60 DAS**
  - Root: 10.51
  - Leaves: 21.17
  - Shoot: 35.87

- **Harvest**
  - Seed: 61.80
  - Root: 16.13
  - Shoot: 46.83

**60 kg S ha$^{-1}$**

- **30 DAS**
  - Root: 2.48
  - Leaves: 4.38
  - Shoot: 24.50

- **60 DAS**
  - Root: 9.82
  - Leaves: 20.50
  - Shoot: 33.70

- **Harvest**
  - Seed: 60.9
  - Root: 15.18
  - Shoot: 44.59
Fig. 3 Effect of K and S on cob girth and cob length (cm) of popcorn

Fig. 4 Effect of K and S on number of cobs/plant, grain number/cob, grain
The application of 40 kg S ha\(^{-1}\) significantly increased the uptake of nutrients by plant parts, improved the yield attributes, growth parameters, ultimately resulted in higher dry matter per plant (leaf, stem, root and seed). The similar findings were also recorded by Dechassa et al., (2013) and Nanthakumar et al., (2014) (Fig. 3).

**Yield attributes**

An appraisal of data (Table 2) showed that various levels of sulphur exerted their significant effect on yield attributes. Application of 40 kg S ha\(^{-1}\) (S\(_3\)) recorded significantly the maximum cob girth (15.58 cm), cob length (17.58 cm), number of cobs per plant (1.43), number of grains per cob (249.63), grain rows per cob (14.83), 100 seed weight (22.08 g), seed weight per cob (55.23 g), dry weight of cob, whereas the lowest was observed with S\(_1\) (control). S improved the nutritional environment and favorably influenced the carbohydrate metabolism due to role of S in energy transformation and activation of enzymes. Rise in different yield attributing characters were also recorded by Dechassa et al., (2013) and Nanthakumar et al., (2014). More number of bigger sized cobs per plant might have accommodated more number of grains providing sufficient space for development of an individual grain, leading to higher 100-grain weight, seed weight per cob and dry weight of cob (Mahmood et al., 1994 and Grobler et al., 1999) (Fig. 4).

**Yield**

The data presented in table 2 indicated that various levels of sulphur manifested their significant influence on seed yield and fodder yield. Application of 40 kg S ha\(^{-1}\) (S\(_3\)) recorded significantly the higher seed yield (3628 kg ha\(^{-1}\)) and fodder yield (6192 kg ha\(^{-1}\)), seed yield was remained at par with S\(_4\) (3489 kg ha\(^{-1}\)) and fodder yield was remained at par with S\(_4\) (5828 kg ha\(^{-1}\)) and S\(_3\) (5671 kg ha\(^{-1}\)). The lowest seed yield and fodder yield were observed under S\(_1\) (control). As these growth and yield attributes as well as nutrients uptake showed significant increase in grain and fodder yields with sulphur fertilization. The similar observations were also recorded by Bhatt and Jain (2012), Sutar (2012), Ahmad et al., (2013) and Nanthakumar et al., (2014).

Based on the experimental results, it can be concluded that significantly the higher seed and fodder yield, yield attributes were obtained from rabi popcorn (cv. Amber) by fertilizing the crop with potassium 60 kg K\(_2\)O ha\(^{-1}\) (K\(_3\)) and sulphur up to 40 kg S ha\(^{-1}\) (S\(_3\)) in medium black calcareous soils of South Saurashtra region of Gujarat.

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