

**INFLUENCE OF CALCIUM, POTASSIUM AND WATERING REGIMES ON
BLOSSOM END ROT IN TWO VARIETIES OF TOMATO (*Solanum lycopersicum*)
IN MANDERA COUNTY, KENYA**

Abstract

Blossom end rot (BER) is one of the physiological disorders of economic importance in tomato farming since it significantly reduces yield and thus affects profit margins. Most tomato disorders are due to mineral deficiencies and unbalanced nutrition. Improving the supply of specific nutrients and uniform soil moisture can reduce their occurrences. This study was conducted to evaluate the influence of watering regimes, Calcium (Ca) and Potassium (K) on blossom end rot occurrence in two tomato varieties in Maslah and Guul sites. The trials were laid out in a randomized complete block design (RCBD) in split-split plot arrangement with watering regimes (daily, thrice and twice a week) as main plots, tomato varieties (Riograde and Rionex) as sub plots, and 3 levels of Ca and K (0 Kg/ha, 25 Kg/ha, 50kg/ha) as the sub-sub plots and replicated three times. Calcium treatments had the lowest score of blossom end rot compared to control. In Guul, the highest BER score (2.83) was observed under the control treatment while the lowest score (1.06) was recorded on the 50kg/ha, Ca rate. Similar results were observed in Maslah with the control having the highest score of BER (3.22) while Ca 50 kg/ha scored lowest (1.11). No statistical differences were observed in the K treatments in the two study sites, however it was notable that lower rates of K reduced the blossom end rot incidences. Water stress led to increase in severity of the BER in the two study sites. In Guul, the highest score was in minimal watering regime (twice a week) of 2.36 score and lowest was at optimal watering regime (daily) of 1.08 score whereas in Maslah the highest blossom end rot score was in minimal watering regime (twice a week) of 3.19 and the lowest score of 1.19 on medium watering regime (Thrice a week). Therefore, optimal application of Ca, K, at 50 kg/ha with adequate and uniform soil moisture can improve management of blossom end rot in tomatoes thus raising farmer's returns.

Key words: BER, Tomato, yield, watering regime, physiological disorders, antagonistic effect

341. Introduction

Blossom end rot (BER) is one of the physiological disorders of economic importance in tomato farming since it significantly reduces yield and thus affecting profit margins [1]. It causes large economic losses in greenhouses and open field tomatoes [2]. The disorder is common in all tomato producing areas of the world especially in hot and dry areas and creates losses of upto 50% [3, 4]. Tomatoes suffering from this disorder have unacceptable quality [5]. The problem was first described as a black rot more than 100 years ago [6, 7]. Blossom end rot is a common disorder that occurs in tomato, pepper, watermelon and egg

42 plant. Since Lyon *et al.*, [8] and Raleigh and Chuka [9] found a correlation between the
43 occurrence of BER and Ca nutrition, BER is now generally attributed to inadequacy of Ca^{2+}
44 in fruits and it is therefore called a calcium-related disorder [10]. Saure [11] stated that BER
45 disorder can be triggered by mechanisms that reduce Ca^{2+} uptake from the soil, fruit Ca^{2+}
46 uptake from the plant and Ca^{2+} translocation within the fruit. These factors result in an
47 abnormal accumulation and partitioning of Ca^{2+} in the cells leading to blossom end rot
48 occurrence. Therefore, poor supply of Ca which has an important role in in the stability of the
49 plasma membrane as well as cell wall [12] is frequently associated with Blossom end rot in
50 tomatoes [13].

51 Blossom End Rot is not caused by single factor (Ca alone) but by a combination of multiple
52 of factors that are high Mg, Na, NH_4^+ and K concentrations [3], accelerated growth rate [14;
53 15], low water availability [16] and low transpiration [17]. Inadequate amounts of Ca for
54 plant growth are rare in most soils, therefore Calcium deficiency is usually as a result of poor
55 distribution of Ca in relation to demand and antagonistic effects of other elements [18]. The
56 calcium concentration in the soil is usually 10 times that of potassium, but the uptake is
57 usually lower for Ca [19]. Calcium is a divalent ion and as ions increase in valency, uptake
58 decreases [20]. Shaykewich *et al.* [21] noted that blossom end rot was not related to Ca
59 deficiency since soil moisture regime influenced BER incidence but not tomato shoot or fruit
60 Ca concentration.

61 The causes of BER are still not fully understood despite many years of research. Further, the
62 relative importance or interaction between inadequate water, calcium and potassium nutrition
63 in the development of BER is still not well understood. Therefore, the objective of this study
64 was to determine the influence of water stress, calcium and potassium on the incidence of
65 blossom end rot in two tomato varieties.

66

672. **Materials and Methods**

68 **2.1 Study area**

69 The study was conducted for two seasons in 2016 in Guul and Maslah sites which lies at
70 latitudes' $3^{\circ}39'42.44''$ and longitudes' $40^{\circ}22'27.266''$ in Takaba, Mandera County, Kenya. The
71 rainfall in the study site is erratic and poorly distributed both in space and time and is
72 bimodal averaging 255mm p.a. The altitude is 760m a.s.l and has temperature range of 22°C
73 during the night and up to 35°C during the day. The agro-ecological zone is arid and semi-
74 arid zone.

75

76 **2.2 Eperimental Design,and Treatments,**

77 The experiments were laid out in a randomized complete block design (RCBD) with split-
78 split plot arrangement with watering regimes (daily, thrice and twice a week) as main plots,
79 tomato varieties (Riograde and Rionex) as sub plots, while 3 levels of Ca and K (0 Kg/ha, 25
80 Kg/ha, 50kg/ha) constituted the sub-sub plots. The treatments were replicated three times.
81 The experiments were conducted between February 2016 and June 2016 (season 1) and
82 between July 2016 and November 2016 (season 2).

83 **2.3 Data Collection and Analysis**

84 All agronomic practices including, watering and weed control were well managed. Maturity
85 determination was determined through visual observation of four tomato fruits for the
86 presence of BER physiological disorder and scored on a scale of on a scale of 0-4.as
87 indicated: 0-None, 1-Low, 2-Mild, 3-Severe, 4-Very Severe.

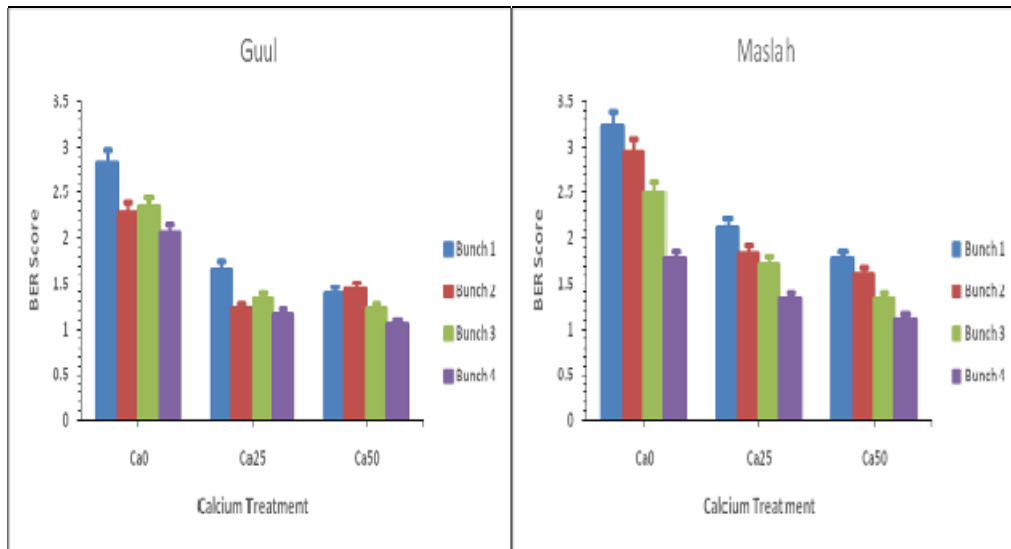
88 Two-way analysis of variance (ANOVA) using GenStat Version 15.1 was used to test levels
89 of significance due to treatments. Where there were significant differences, Fischer's
90 Protected LSD tests were performed to separate the treatment means at 5% probability level.
91 Regression analysis between watering regimes and BER incidences were performed.

92

93 **3. Results and Discussions**

94 **3.1 Influence of Calcium treatments on Blossom end rot in tomatoes**

95 There were significant differences ($P \leq 0.05$) in Blossom end rot score across the flower
96 bunches due to calcium treatment in both sites but they were not significant (Figure 1). In
97 Guul the highest blossom end rot score of 2.83 in bunch 1 under the treatment without Ca
98 supply, while the lowest blossom end rot score of 1.06 was in flower bunch 4 under
99 50Kg/haCa treatment. In Maslah the highest blossom end rot score (3.22) was under
100 treatment without Ca supply and the lowest score (1.11) was in flower bunch 4 at 50Kg/ha
101 Ca. The study revealed that Ca plays a role in causing, controlling or managing blossom end
102 rot. This was observed from the treatment without Ca supply which apparently showed the
103 highest incidences of the physiological disorder as opposed to those with the highest Ca
104 application rate that had the lowest incidences of blossom end rot.



105

106 Figure 1: Influence of Calcium levels on Blossom end rot in two tomatoes varieties in two
 107 different sites (Gul and Malah).

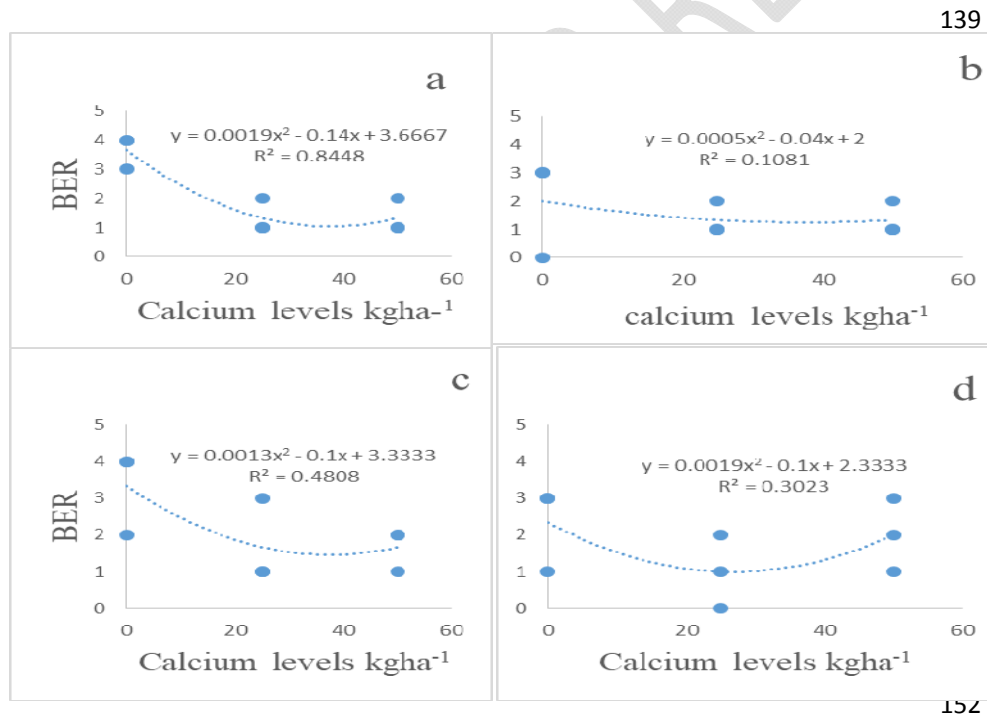
108 The observed high incidence of BER associated with less Ca in agreement with the findings
 109 of Lyon *et al.* [8] who reported a correlation between Ca and blossom end rot occurrence.
 110 Later work by other workers [9] supported the findings and since then to date the disorder is
 111 attributed to Ca inadequacy. However, many studies have revealed that Ca is not the sole
 112 cause or predisposing of blossom end rot. Plant's response to other factors like nutrition,
 113 ambient and root environments that lower the Ca content in the fruit can also induce this
 114 disorder [23, 24]. Evidence for Ca deficiency as one of the causes of blossom end rot arises
 115 from the observations that fruit affected by blossom end rot always had a lower Ca content as
 116 compared to health fruit [16].

117 The study also revealed that even in occasions of high Ca content or application rates,
 118 incidences of blossom end rot were observed but at lower score. This concurs with the
 119 findings of previous workers [25, 26, 27] who reported blossom end rot occurrence in plants
 120 even with high Ca status. Franco *et al.* [17] observed a serious blossom end rot incidence
 121 despite fairly high levels of Ca^{2+} in the distal parts of the fruit. Nukaya *et al.* [28] also
 122 reported that blossom end rot might be a serious problem despite a fairly high level of Ca in
 123 the distal part of the fruit.

124 In contrary there is some evidence that Ca deficiency is not the cause of blossom end rot, as a
 125 critical level of Ca for blossom end rot induction was not found. Nonami *et al.* [29] argued
 126 that blossom end rot might not be directly related to Ca deficiency. Research also did not find
 127 strong evidence that Ca was the main cause of blossom end rot [16].

128 **3.2 Relationship between blossom end rot (BER) and Calcium levels of tomato varieties**
129 **under different watering regimes in Guul and Maslah**

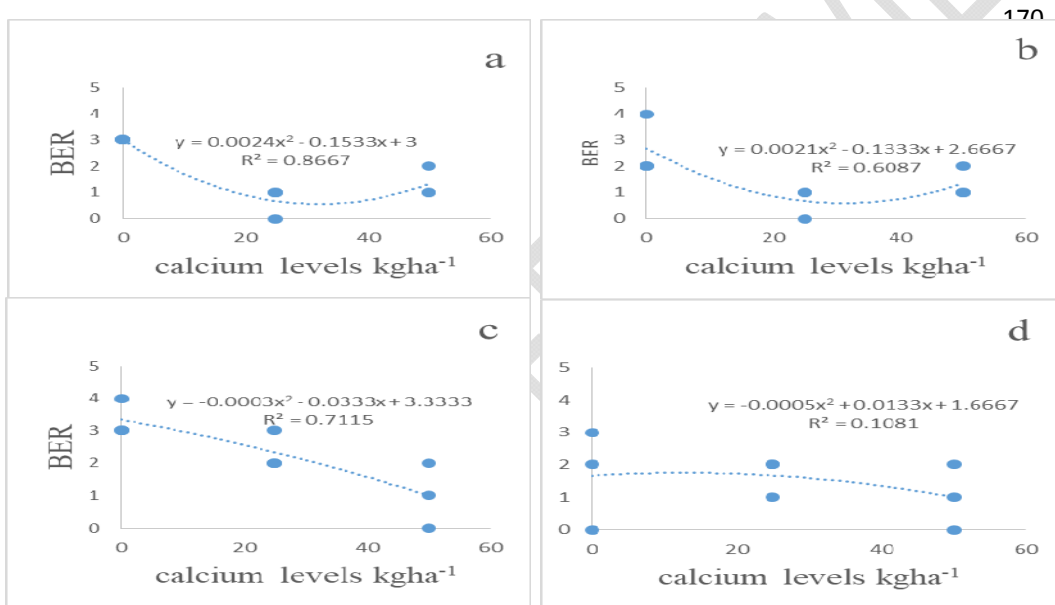
130 In both sites, the regression analysis showed that blossom end rot (BER) incidence
131 significantly correlated with calcium levels. There was a negative relationship between
132 blossom end rot occurrence and calcium levels in both watering regimes (Figures 2 and 3)
133 whereby as calcium levels increased the incidence of BER decreased under the Riograde
134 variety. The highest variation in BER occurrence (R^2 value of 0.84) observed under optimal
135 watering regime (daily) in flower bunch one in Guul and R^2 value of 0.72 in flower bunch
136 two under minimal watering regime (twice a week) in Maslah could be attributed to low Ca
137 concentration during the rapid growth of tomato fruits as a result of low Ca levels in the soil
138 for uptake by the tomato plants [30].



153 **Figure 2: Regression analysis of blossom end rot(BER) and calcium levels for tomato**
154 **Riograde variety in Guul study site (a) bunch one daily irrigation, (b)bunch two daily**
155 **irrigation, (c)bunch one on twice irrigation (d) bunch two twice irrigation**
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157 The negative relationship could also be due to increase in phloem transport of assimilates
158 without an increase in xylem transport of Ca during accelerated fruit growth. The gain of dry

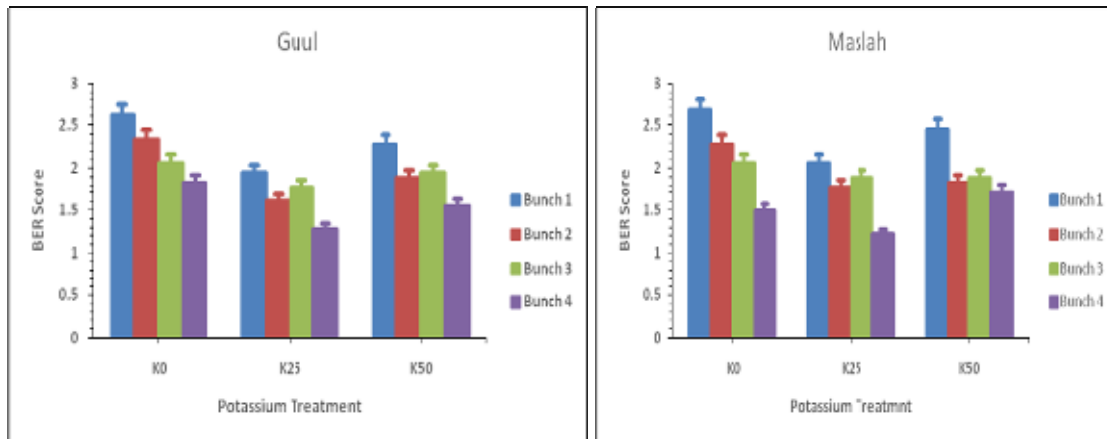
159 matter and water in the tomato fruit is supplied by phloem transport while accumulation of
 160 Ca is thought to be limited by xylem transport [31]. Hence, an imbalance between transport
 161 of assimilates and Ca during accelerated growth could be the common cause of BER in
 162 tomatoes. Meanwhile, enhanced import of assimilates may be accompanied by enhanced
 163 import of K available in the soil, thus the cause of BER may not be entirely caused by low Ca
 164 status but due to high K/Ca ratio in the fruit tissue as reported by [32, 33]. In Fig. 2 bunch 2
 165 under minimal watering regime (twice a week) and Fig.3 bunch 2 under daily watering
 166 regime demonstrated that there is limit in calcium level application after which the BER
 167 incidence increases beside high Ca application rate or possibly there could be other causes as
 168 suggested by Nonami *et al.* [29] that Ca deficiency is not the only cause of BER as the
 169 critical level of Ca for BER induction was not found.



182 **Figure 3: Regression analysis of blossom end rot(BER) and calcium levels for tomato**
 183 **Rionex variety in Maslah study site (a) bunch one daily irrigation, (b)bunch two daily**
 184 **irrigation, (c)bunch one twice irrigation (d) bunch two twice irrigation**
 185

1863.3 Influence of Potassium treatments on Blossom end rot in tomatoes

187 There were differences in Blossom end rot score across flower bunches due to potassium
 188 treatment in both sites even though they were not significant. In Guul the highest blossom
 189 end rot score (2.61) was observed in flower bunch 1 under the treatment without K supply
 190 whereas the lowest score (1.28) was recorded in flower bunch 4 under treatment 25Kg/ha K
 191 (Figure 4).



192

193 **Figure 4: Influence of Potassium on Blossom end rot in tomatoes**

194

195 In Maslah the highest blossom end rot score (2.67) was observed in flower bunch 1 under the
 196 treatment without K supply. The lowest score (1.22) was in flower bunch 4 under the
 197 treatment 25Kg/ha K. The study revealed that application of K at low rate had low incidences
 198 of blossom end rot when compared to high K application rate which had higher incidences of
 199 blossom end rot nearing the treatment without K supply which demonstrated that K is not
 200 very essential in blossom end rot control. This could be attributed to the fact that high K
 201 concentration competed with the available Ca in the soil (antagonism); reducing Ca uptake by
 202 the tomato plants leading to its deficiency thus accelerating blossom end rot occurrence. This
 203 is in agreement with the observations of other researchers [3, 4, 9, 35] who reported that high
 204 K in tomato increased Blossom end rot. However, Stevens and Rick [36], found very poor
 205 correlations among incidence of blossom end rot (BER), concentrations of Ca and K, and the
 206 K/Ca ratio in ripe tomato fruits. The antagonism is not limited to Ca and K alone but other
 207 cation elements [37, 38, 39].

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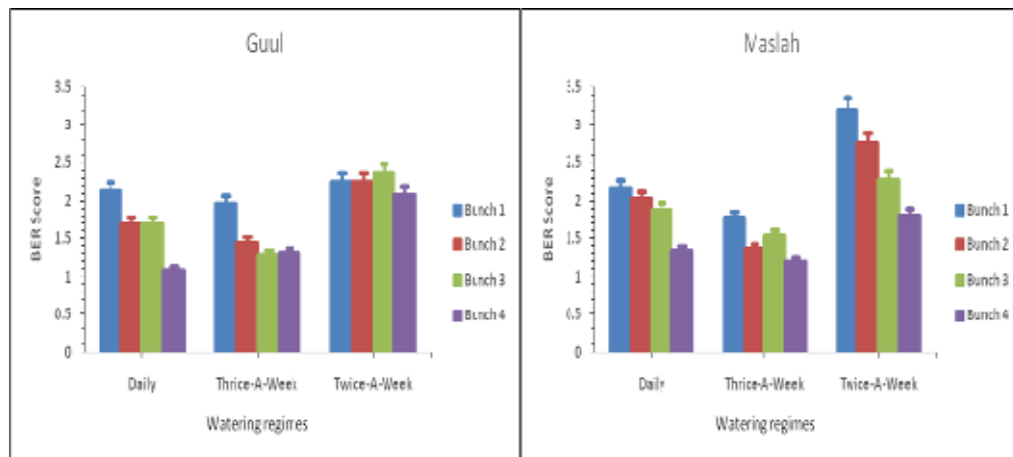
209 **3.4 Effects of watering regimes on Blossom end rot (BER) in tomatoes**

210 In both sites there were no significant differences observed between flower bunches across
 211 the watering regimes on blossom end rot score. In Guul the highest blossom end rot score
 212 was 2.36 in flower bunch 3 under minimal (twice a week) watering regime, while the lowest
 213 score of 1.08 in bunch 4 was recorded under adequate (daily) watering regime. The moderate

214 (thrice a week) had the lower blossom end rot score across the bunches compared to other
215 regimes in all flower bunches.

216 In Maslah watering twice a week had higher blossom end rot score compared to the other
217 watering regimes with 3.19 score being the highest in bunch 1 while the lowest score was
218 1.19 in bunch 4 under moderate (twice a week) watering regime as shown in Fig.5.

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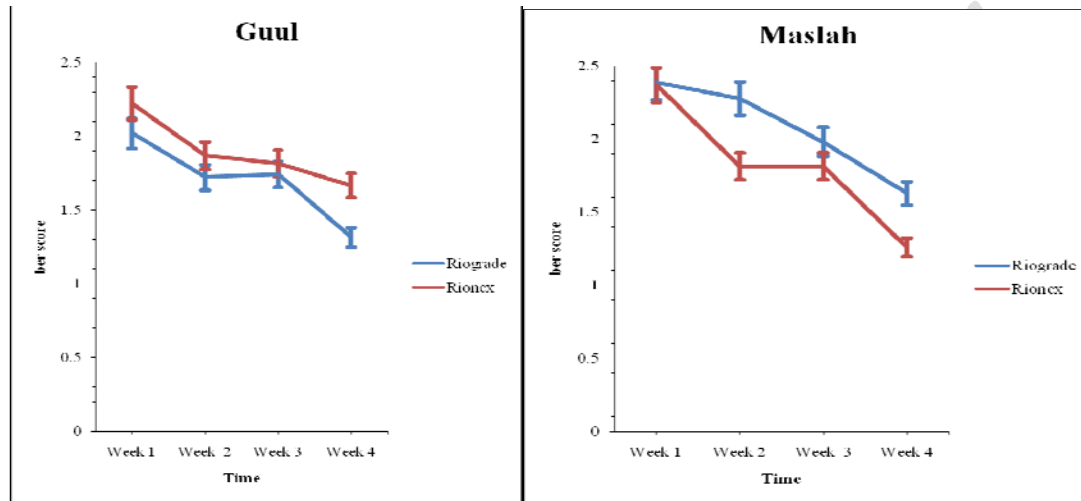
221 **Figure 5: Effects of watering regimes on Blossom end rot in tomatoes in two different**
222 **sites (Guul and Maslah)**

223

224 The study revealed that the disorder occurred under all watering regimes but severity
225 increased with increase in water stress. There existed, possibility that even in well watered
226 soil, plants may have still suffered water stress. This concurs with earlier findings [22] which
227 reported that blossom end rot increased in plants grown in soils with low moisture and
228 Kataoka *et al.* [40] further observed that the occurrence of blossom end rot is enhanced by
229 water stress. The findings are also in agreement with Stevens and Rick [36] who observed
230 that susceptibility to blossom end rot varies tremendously among tomato cultivars and is
231 usually associated with changes in soil moisture content but the findings differ from those of
232 Wada *et al.* [41] who reported that soil moisture level had no effect on incidence of blossom
233 end rot, fruit cracking and zippers in field grown fresh market tomatoes.

234 **3.5 Effects of time of growth on Blossom end rot (BER) in tomato varieties in Guul and**
235 **Maslah**

236 There were no significant differences recorded on blossom end rot between varieties in both
237 sites. In Guul the highest score was observed in Rionex in week 1 with a score of 2.22 and
238 the lowest blossom end rot score was observed in Riograde under week 4 with a score of
239 1.32. Both varieties demonstrated a decreasing trend in blossom end rot score over time in
240 weeks as season advanced (Figure 6).



241
242 **Figure 6: Effects of time on Blossom end rot (BER) in tomato varieties in Guul and**
243 **Maslah**

244 In Maslah the highest BER score was recorded under Riograde variety (2.39) in week 1 while
245 the lowest was under Rionex (1.26) in week 4. Both varieties demonstrated a decreasing trend
246 in blossom end rot score over time in weeks as shown in Figure 6. The study revealed that
247 blossom end rot is higher in first fruits that form during reproductive phase and decreases as
248 the season advances. Different varieties have varied capacity on susceptibility to blossom end
249 rot depending on genetic composition, growth characteristics, ability to distribute and
250 partitioned nutrients to various plant organs for uniform growth and development. There are
251 similar observations from various researchers that show clear genetic influence in the
252 susceptibility of different cultivars to blossom end rot and does appear to be related to fruit
253 growth rate and potential fruit size among cultivars i.e. fruit shape and fruit expansion rate
254 [42, 43, 26, 44]. Blossom end rot could be a consequence of anatomical problem rather than a

255 cellular signal triggered by lack of Ca perceived at genetic level of cultivars as raised by Ho
256 and White [45]. This difference is shown in two varieties (Riogrande and Rionex).

257

2584. **Conclusion**

259 We conclude Application of 50kg/ha of Ca and 25Kg/ha, K had the lowest BER Score while
260 minimal watering regime (twice a week) was among the highest BER score candidates
261 whereas moderate watering regime (Thrice a week) had the lowest BER score. On the other
262 hand, control (no application of Ca or K) was among the highest BER scorer.

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265 **COMPETING INTERESTS**

266 Authors have declared that no competing interests exist

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