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Influence of Calcium, Potassium and Watering Regimes on Blossom End Rot in Two Varieties of Tomato (*Solanum lycopersicum*) in Mandera County, Kenya

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Authors' contributions

This work was carried out in collaboration among all authors. Author MPS designed the experiment, corrected data, and developed the first manuscript draft. Authors WNW and NW analyzed the data and read the manuscript. Author NKK reviewed the experimental design and read the manuscript while author JGO conceptualized the idea, guided on collection of the study and read the final manuscript. All authors read and approved the final manuscript.

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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, 50 kg/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

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(2.83) was observed under the control treatment while the lowest score (1.06) was recorded on the 50 kg/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.

Keywords: BER; Tomato; yield; watering regime; physiological disorders; antagonistic effect.

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

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

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

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted for two seasons in 2016 in Guul and Maslah sites which lies at latitudes' 3°394244 and longitudes' 40°227266 in Takaba, Mandera County, Kenya. The rainfall in the study site is erratic and poorly distributed both in space and time and is bimodal averaging 255 mm p.a. The altitude is 760 m a.s.l and has temperature range of 22°C during the night and up to 35°C during the day. The agro-ecological zone is arid and semi-arid zone.

2.2 Eperimental Design, and Treatments

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

2.3 Data Collection and Analysis

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

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

3. RESULTS AND DISCUSSION

3.1 Influence of Calcium Treatments on Blossom end rot in Tomatoes

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

The observed high incidence of BER associated with less Ca is in agreement with the findings of Lyon et al. [8] who reported a correlation between Ca and blossom end rot occurrence. Later work by other workers [9] supported the findings and since then to date the disorder is attributed to Ca inadequacy. However, many studies have revealed that Ca is not the sole cause or predisposing factor for blossom end rot. Plant's response to other factors like nutrition, ambient and root environments that lower the Ca content in the fruit can also induce this disorder [22,23]. Evidence for Ca deficiency as one of the causes of blossom end rot arises from the observations that fruit affected by blossom end rot always had a lower Ca content as compared to health fruit [16].

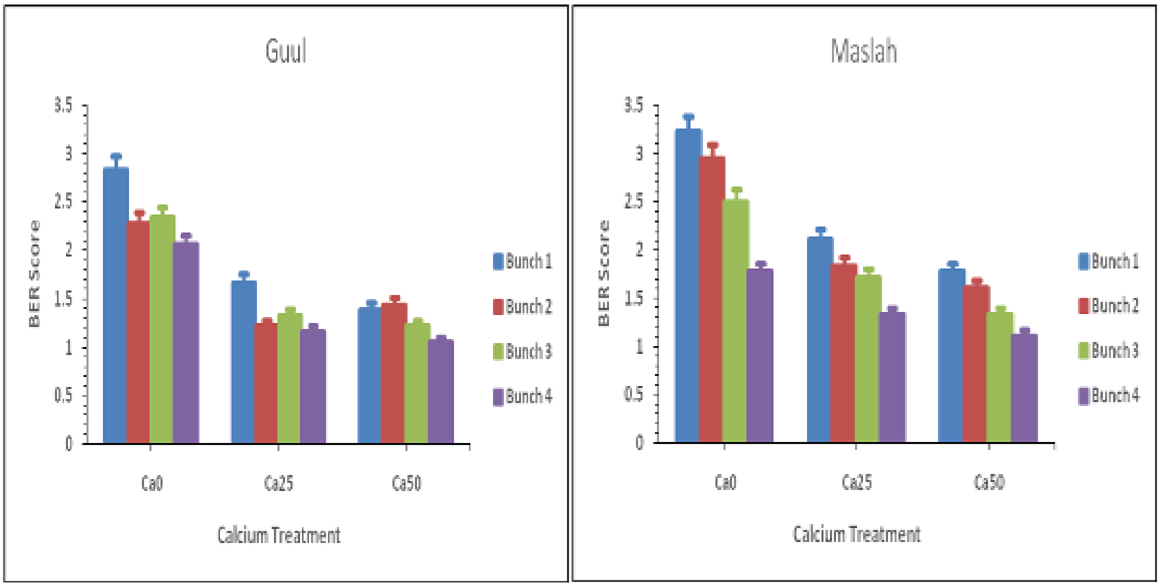

Fig. 1. Influence of Calcium levels on Blossom end rot in two tomatoes varieties in two different sites (Guul and Malah)

The study also revealed that even in occasions of high Ca content or application rates, incidences of blossom end rot were observed but at lower score. This concurs with the findings of previous workers [24,25,26] who reported blossom end rot occurrence in plants even with high Ca status. Franco et al. [17] observed a serious blossom end rot incidence despite fairly high levels of Ca^{2+} in the distal parts of the fruit. Nukaya et al. [27] also reported that blossom end rot might be a serious problem despite a fairly high level of Ca in the distal part of the fruit.

In contrary there is some evidence that Ca deficiency is not the cause of blossom end rot, as a critical level of Ca for blossom end rot induction was not found. Nonami et al. [28] argued that blossom end rot might not be directly related to Ca deficiency. Research also did not find strong evidence that Ca was the main cause of blossom end rot [16].

3.2 Relationship between Blossom End Rot (BER) and Calcium Levels of Tomato Varieties under Different Watering Regimes in Guul and Maslah

In both sites, the regression analysis showed that blossom end rot (BER) incidence significantly correlated with calcium levels. There was a negative relationship between blossom end rot occurrence and calcium levels in both watering regimes (Figs. 2 and 3) whereby as calcium levels increased the incidence of BER decreased under the Riograde variety. The highest variation in BER occurrence (R^2 value of 0.84) observed under optimal watering regime (daily) in flower bunch one in Guul and R^2 value of 0.72 in flower bunch two under minimal watering regime (twice a week) in Maslah could be attributed to low Ca concentration during the rapid growth of tomato fruits as a result of low Ca levels in the soil for uptake by the tomato plants [29].

The negative relationship could also be due to increase in phloem transport of assimilates without an increase in xylem transport of Ca during accelerated fruit growth. The gain of dry matter and water in the tomato fruit is supplied by phloem transport while accumulation of Ca is thought to be limited by xylem transport [30]. Hence, an imbalance between transport of assimilates and Ca during accelerated growth could be the common cause of BER in tomatoes. Meanwhile, enhanced import of assimilates may be accompanied by enhanced import of K available in the soil, thus the cause of BER may not be entirely caused by low Ca status but due to high K/Ca ratio in the fruit tissue as reported by [31,32]. In Fig. 2 bunch 2 under minimal watering regime (twice a week) and Fig.3 bunch 2 under daily watering regime demonstrated that there is limit in calcium level application after which the BER incidence increases beside high Ca application rate or possibly there could be other causes as suggested by Nonami et al. [28] that Ca deficiency is not the only cause of BER as the critical level of Ca for BER induction was not found.

3.3 Influence of Potassium Treatments on Blossom end Rot in Tomatoes

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

In Maslah the highest blossom end rot score (2.67) was observed in flower bunch 1 under the treatment without K supply. The lowest score (1.22) was in flower bunch 4 under the 25 Kg/ha K treatment. The study revealed that application of K at low rate had low incidences of blossom end rot when compared to high K application rate which had higher incidences of blossom end rot nearing the treatment without K supply which demonstrated that K is not very essential in blossom end rot control. This could be attributed to the fact that high K concentration competed with the available Ca in the soil (antagonism); reducing Ca uptake by the tomato plants leading to its deficiency thus accelerating blossom end rot occurrence. This is in agreement with the observations of other researchers [3,4,9,33,34] who reported that high K in tomato increased Blossom end rot. However, Stevens and Rick [35], found very poor correlations among incidence of blossom end rot (BER), concentrations of Ca and K, and the K/Ca ratio in ripe tomato fruits. The antagonism is not limited to Ca and K alone but other cation elements [36,37,38].

3.4 Effects of Watering Regimes on Blossom end Rot (BER) in Tomatoes

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

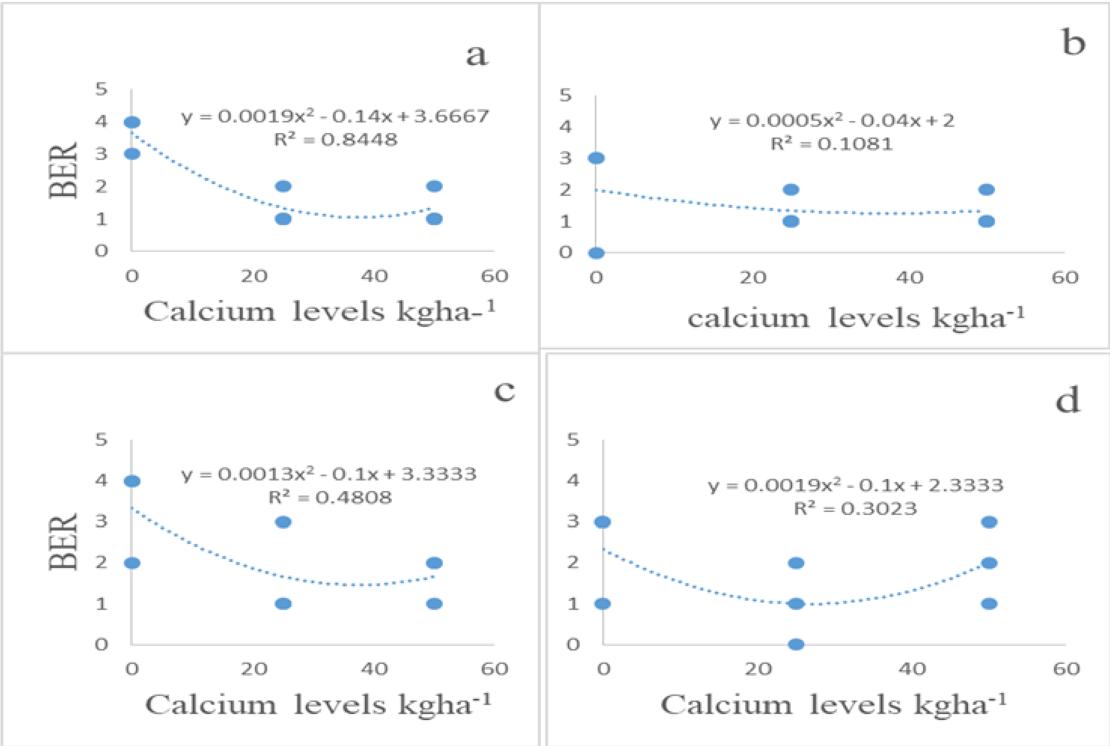

Fig. 2. Regression analysis of blossom end rot (BER) and calcium levels for tomato Riograde variety in Guul study site (a) bunch one daily irrigation, (b) bunch two daily irrigation, (c) bunch on twice irrigation (d) bunch two twice irrigation

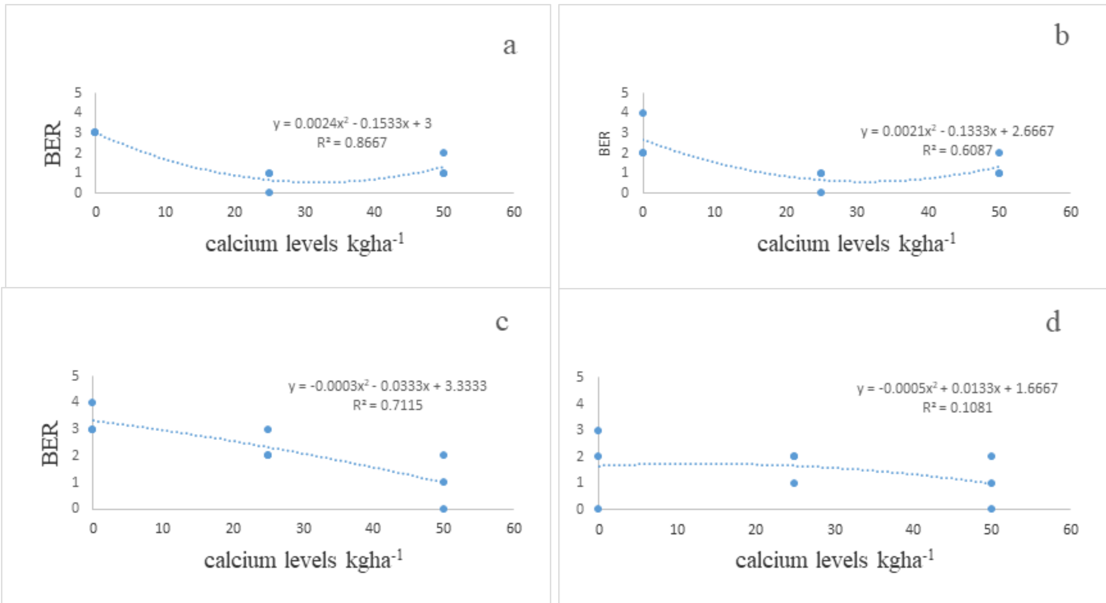

Fig. 3. Regression analysis of blossom end rot (BER) and calcium levels for tomato Rionex variety in Maslah study site (a) bunch one daily irrigation, (b)bunch two daily irrigation, (c) bunch one twice irrigation (d) bunch two twice irrigation

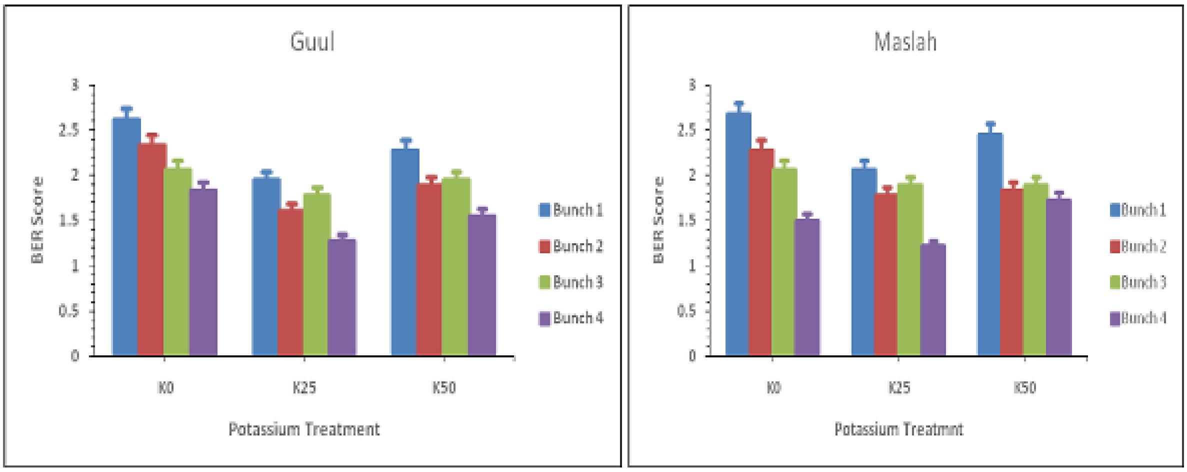

Fig. 4. Influence of Potassium on Blossom end rot in tomatoes

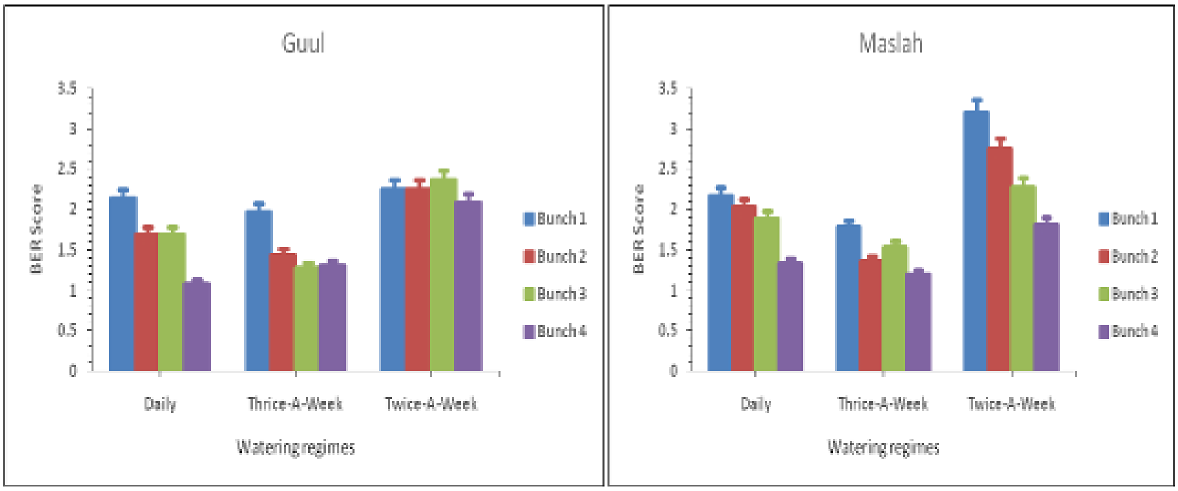

Fig. 5. Effects of watering regimes on Blossom end rot in tomatoes in two different sites (Guul and Maslah)

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

The study revealed that the disorder occurred under all watering regimes but severity increased with increase in water stress. There existed, possibility that even in well watered soil, plants may have still suffered water stress. This concurs with earlier findings [39] which reported that blossom end rot increased in plants grown in soils with low moisture and Kataoka et al. [40] further observed that the occurrence of blossom end rot is enhanced by water stress. The findings are also in agreement with Stevens and Rick [35] who observed that susceptibility to blossom end rot varies tremendously among tomato cultivars and is usually associated with changes in soil moisture content but the findings differ from those of Wada et al. [41] who reported that soil moisture level had no effect on incidence of blossom end rot, fruit cracking and zippers in field grown fresh market tomatoes.

3.5 Effects of Time of Growth on Blossom End Rot (BER) in Tomato Varieties in Guul and Maslah

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

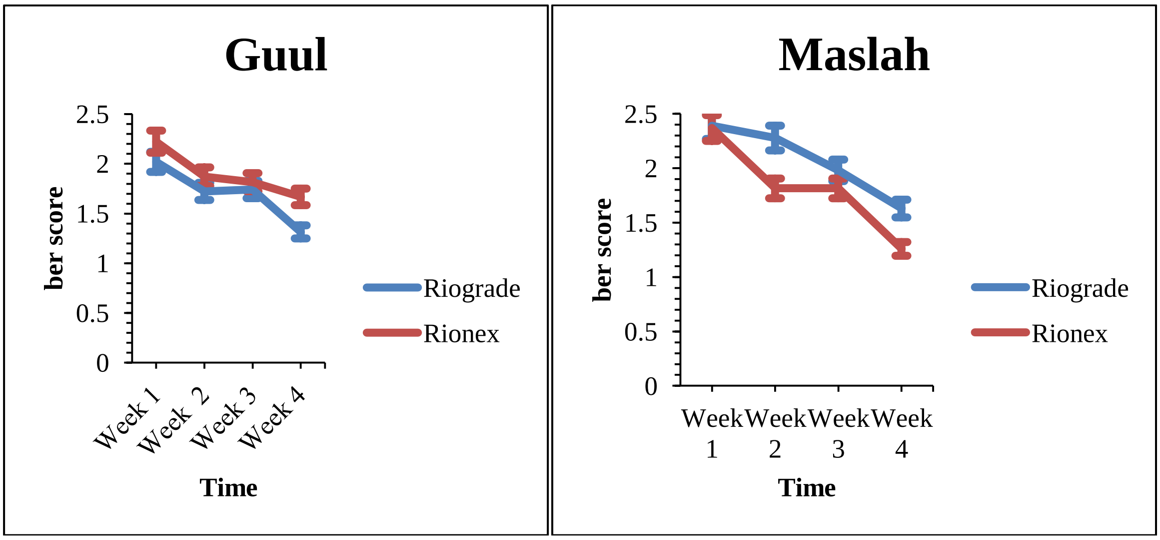

Fig. 6. Effects of time on Blossom end rot (BER) in tomato varieties in Guul and Maslah

In Maslah the highest BER score was recorded under Riograde variety (2.39) in week 1 while the lowest was under Rionex (1.26) in week 4. Both varieties demonstrated a decreasing trend in blossom end rot score over time in weeks as shown in Fig. 6. The study revealed that blossom end rot is higher in first fruits that form during reproductive phase and decreases as the season advances. Different varieties have varied capacity on susceptibility to blossom end rot depending on genetic composition, growth characteristics, ability to distribute and partitioned nutrients to various plant organs for uniform growth and development. There are similar observations from various researchers that show clear genetic influence in the susceptibility of different cultivars to blossom end rot and does appear to be related to fruit growth rate and potential fruit size among cultivars i.e. fruit shape and fruit expansion rate [42,43,25,44]. Blossom end rot could be a consequence of anatomical problem rather than a cellular signal triggered by lack of Ca perceived at genetic level of cultivars as raised by Ho and White [45]. This difference is shown in two varieties (Riogrande and Rionex).

4. CONCLUSION

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

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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