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## Effects of Cabbage Tissue and Calcium Hypochlorite on Soil Fertility and Yields of Selected Solanaceous Crops

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### Authors' contributions

*This work was carried out in collaboration amongst all authors. Author EKK designed the experimental plots, carried out field and laboratory experiments and made the write-up and collected the relevant data. Author ZMK supervised the experiments and offered financial assistance through the ASARECA project. Authors POO and JMM made follow ups to the Experiments, write –ups and performed the statistical analysis. All authors read and approved the final manuscript.*

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### ABSTRACT

The objective of this study was to determine the effect of inorganic compounds treatment(s) namely: Chalim<sup>TM</sup> (CM), a chlorine-containing compound, metham sodium (MS) (positive control) and Co (negative control) versus organic compound such as *Brassica* tissue treatment (BT), on soil pH, micro and macroelements. Three levels of Chalim<sup>TM</sup> and that of *Brassica* tissue; one of MS and one for Co were used. The test crops included were; Tomato, capsicum and potato. All the plots were inoculated with *R. solanacearum* to a level of approximately  $7.5 \times 10^7$  Colony forming unit (CFU) per plot. Soil samples were taken using zigzag method after which the selected parameter levels were determined at the beginning and at the end of each season for three seasons (2009-2010). The amendments were prepared and applied in the field plots measuring (4.5×2.7 M) in randomized complete block design at Kenya agricultural research institute National agricultural laboratories in plant pathology section and Department of Plant and Microbial Sciences, Kenyatta university. The effects of the soil amendments on soil physico-chemical properties and yields were determined. The findings established that, *Brassica* tissue, at highest level of

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application was the best soil amendment to be incorporated since more nutrients and yields were realized at that treatment as compared to the others. The various treatments differed significantly on their effect on the total yields. In tomato, the various treatments differed significantly ( $P < 0.05$ ) with plants grown on MS200 and BT5292 having significantly higher yields than the control. The study revealed that BT5292 increased the soil pH, yields, Nitrogen content, organic carbon, calcium and potassium concentration as compared to the other treatments and the control.

**Keywords:** *Inorganic compounds; cabbage tissue; yields; amendments; nutrients; Solanaceous crops; soil physico-chemical properties.*

## 1. INTRODUCTION

Some soil amendments boost the macro and micronutrients and hence the need to investigate them. Others reduce disease incidence while others increase crop yields. Farmers are reportedly using organic amendments all the time on soil fertility management [1]. However, the use of *cabbage* tissue and calcium hypochlorite for improving the soil fertility has not been reported in Kenya.

Solanaceous crops are sensitive plants that can be affected by weather conditions for example cold and wet conditions that may cause late blight. The crops are greatly affected by diseases and pests in addition to exhausting soil nutrients that needs to be replenished by artificial means. Soil amendments with inorganic and organic mixtures reduce bacterial wilt incidence in some locations, but more research is required to provide explicit and economically feasible types of material and doses for reliable disease management [2].

The provision of nutrients to the plant in quantities that are optimal for their subsequent utilization is a primary aim of crop fertilizer programme since yields and quality are adversely affected by any deviation [3]. Nitrogen addition at planting is effective against bacterial wilt [4]. Earlier studies concerned with the effects of nitrogen source on tomato and its interactions with other nutritional and environmental factors indicated that, tomato is susceptible to the supply of ammonium as a sole nitrogen form [3]. According to [3], the use of ammonium as dominating N source in a solution culture of tomato resulted in impaired growth and yield restrictions. These restrictions include both vegetative growth and the fruit yield of tomato when  $\text{NH}_4\text{-N}/\text{total Nitrogen}$  in the nutrient solution was higher than 0.1. The impaired growth of tomato when the ammonium fraction was in the range 0.15- 0.25 of the total Nitrogen supply was associated with low pH levels ( $<5$ ) in the root zone. Investigations on the effect of N on yield of tomatoes indicated that percentage defoliation of plants decreased with increasing N and K rates; however there was no concomitant increase in marketable tomato yield [5].

According to [3], modern tomato cultivars and hybrids exhibit high relative growth rates and require adequate supply of phosphorus (P) for optimal development and high yields. Harold also reported that, the relative growth rate increases sharply with increasing P concentrations enhancing chlorophyll II, potassium, magnesium and iron thus increasing fruit yields and quality. The potassium (K) requirements of tomato are high due to the rapid growth of the plant in combination with the heavy fruit load [6]. To cope with high potassium requirements, tomato has evolved efficient mechanisms to acquire potassium under

conditions of low potassium levels in the root zone [7]. According to [3], tomatoes grown in potassium deficient soils shown severe depression.

Research has shown that, a low calcium level in the root zone is rarely a limiting factor for the vegetative growth of tomato [3]. Nevertheless the nutrient is intimately involved in the occurrence of a physiological disorder Blossom End Rot (BER) [8]. Other findings have indicated that calcium deficiency can not suppress bacterial wilt and thus does not play a key role in BW resistance [9]. Manganese deficiency has been found to cause severe restriction to growth of vegetable especially tomato. Too low or too high Mn concentrations in the root zone restrict growth. Contrary to these findings, too high levels of magnesium in the root zone have been known to be beneficial to tomato [3]. Research has shown that, *R. solanacearum* can be significantly reduced by treatment with silicon fertilizer [10]. According to these findings, the mean bacterial wilt disease incidence and percent severity index were significantly lower with silicon fertilizer treatment. Moderately resistant cultivar had a final mean bacterial wilt disease incidence reduction of 51.6 and 57.8% respectively. Investigations conducted to demonstrate the effects of salinity on tomato indicated that, the crop is moderately sensitive to salinity. The study indicated that, increasing the salt concentrations to levels higher than 2.5-2.9 dS m<sup>-1</sup> in the root zone affects the number of fruits per plant [3].

## **2. MATERIALS AND METHODS**

### **2.1 Soil Amendments and Field Inoculation**

The selected parameter levels were determined at the beginning and at the end of each season for three seasons (2009-2010). Three sample crops (tomato, capsicum and potato) were used where Randomized complete split plot design was used in the field layout of 4.5 x 2.7M. The amendments of the *Brassica* were at the rate of; 5292 g (4355.56 kg/ha), 3096 g (2548.15 kg/ha) and 1908 g (1570.37 kg/ha) with three replicates of each metham sodium, a chemical fumigant was applied in 3 plots at the rate of 200 MI/M<sup>2</sup> (2.43 L in 12.15 L of water). This was the positive control. This was in 9 furrows where each furrow received 1562ml of the mixture. The sprayed furrows were thereafter covered with soil awaiting three weeks to planting of the test crops. Cholim™ effect was assessed in the inoculated field after application at varying concentrations of 911.25 g (750 kg/ha), 607.5 g (500 kg/ha), and 303.75 g (250 kg/ha). All the plots were inoculated with *R. solanacearum* to a level of approximately  $7.5 \times 10^7$  Colony forming unit (CFU) per plot.

### **2.2 Soil Sampling**

Soil sampling for analysis was done before soil amendments and three months after planting where 48 buckets, two per plot were assembled for soil sampling where one bucket was for the top soil and the other for the subsoil. The earth was cut using a soil auger to a depth of about 20 cm and transferred into a bucket for top soil [11]. The soil samples were then transferred to the KARI-NARL, Kenya soil laboratory for soil testing and analysis.

#### **2.2.1 Soil analysis for available nutrient elements (K, Na, Ca, Mg and Mn)**

Available nutrient elements (K, Na, Ca, Mg and Mn) were determined by Mehlich Double Acid Method [12]. The oven-dried soil samples at 40<sup>0</sup> C were extracted in a 1:5 ratio (w/v) with a mixture of 0.1 N HCl and 0.025 N H<sub>2</sub>SO<sub>4</sub>. The concentrations of Na, Ca and K were

determined using flame atomic absorption spectrophotometry (AAS) (Perkin Elmer 1100B) [13]. P was determined by the Vanadate-molybdate method [14].

### **2.2.2 Soil analysis for total organic carbon**

Analysis of total soil organic concentration was performed at KARI-NARL in Nairobi, Kenya using the colorimetric method. This method is a wet oxidation procedure that uses potassium dichromate with external heat as described by [15]. All organic Carbon in the soil sample was oxidized by acidified dichromate at 150°C for 30 minutes to ensure complete oxidation. Barium chloride was added to the cool digests. After mixing thoroughly digests were allowed to stand overnight. The Carbon concentration was read on the spectrophotometer at 600 nm.

### **2.2.3 Soil analysis for total nitrogen**

Total nitrogen was determined by Kjeldahl method [16]. Soil samples were digested with concentrated sulphuric acid containing potassium sulphate, selenium and copper sulphate hydrated at approximately 350°C. Total N was determined by distillation followed by titration with diluted standardized 0.007144N H<sub>2</sub>SO<sub>4</sub>.

### **2.2.4 Soil analysis for pH and EC**

Soil pH and Electrical Conductivity were determined in a 1:1 (w/v) soil measured using a pH and Conductivity meter. A crison digital 501 pH was used. Electrical conductivity was measured in the saturated water extract [17] with a crison 522 conductimeter

### **2.2.5 Soil analysis for available trace elements (Fe, Zn & Cu)**

The oven-dried soil samples were extracted in a 1:10 ratio (w/v) with 0.1 M HCl. A SpectrAA-40 atomic absorption spectrometer, PSC-56 programmable sample changer, Epson LX-80 printer, and Cu, Zn, Fe, Ca, Mg, Na and K hollow cathode lamps from Agilent Technologies, Inc. were used in the procedure.

## **3. RESULTS AND DISCUSSION**

### **3.1 Effect of Treatments on Moisture Content, pH and Yields**

There were significant differences in the r-values (positive) for total weight against total number of tubers/fruits, tubers without external wilt symptoms, fresh weight of roots, dry weight of roots, fresh weight of shoots, and dry weight of shoots. Total number of tubers had significantly high r-value  $r=0.904$  compared to number of plants wilted  $r=-0.428$  ( $p<0.01$ ). However, the other parameters had significant r-values higher than 0.6. The positively significant relationship indicates that dry weight increased with a corresponding increase from each of these parameters except for number of plants wilted. Total number of tubers/fruits increased significantly with increase in these parameters. Tubers without external wilt symptoms had the highest r-value;  $r=1.00$  that was significantly different at  $p<0.01$  level (Table 1). The correlation between total number of tubers/fruits and number of plants wilted was significant and negative  $r=-0.426$ ; i.e. total number of tubers/fruits decreased significantly with increase in the number of number of plants wilted.

There was significant difference in r-value for number tubers with external wilt symptoms against plants wilted. Number tubers with external wilt symptoms increased significantly with increase in the number of plants wilted  $r=0.291$   $p<0.01$ .

There were significant differences in the r-values for the number of plants wilted against total weight, total number of tubers/ fruits, tubers with external wilt symptoms, fresh weight of roots, dry weight of roots, fresh weight of shoots and dry weight of shoots. Fresh weight of shoots had the highest r-value ( $r=-0.520$ )  $p<0.01$ , compared to tubers with external wilt symptoms ( $r=0.291$ ),  $p<0.05$ . There were significant differences in the r-values for fresh weight of roots against total weight (g), total number of tubers/fruits, tubers without external wilt symptoms, number of plants wilted, dry weight of roots, fresh weight of shoots, dry weight of shoots. The highest significant r-value was achieved in dry weight of shoots ( $r=0.790$ )  $p<0.01$  compared to number of plants wilted ( $r=-0.448$ ),  $p<0.01$ . Dry weight of roots, fresh weight of shoots and dry weight of shoots increased significantly with increase in the Fresh weight of roots.  $P<0.01$  level of probability (Table 1). There were significant differences in r-values for fresh weight of shoots and dry weight of shoots across all parameters except in tubers with external wilt symptoms, pH and average MC. Fresh weight of roots, dry weight of roots, fresh weight of shoots and dry weight of shoots significantly reduced with increase in the number of plants wilted.  $P<0.01$  level of probability (Table 1). There were significant differences for dry weight of roots across all parameters except in average MC, pH and tubers with external wilt symptoms. Fresh weight of shoots and dry weight of shoots increased significantly with increase in the dry weight of roots.  $P<0.01$  level of probability (Table 1). Where dry root weight and shoot weight of disease-free plants total was higher. The increase in weight could be attributed to high nutrient contents from the soil amendments. This accords with [18, 19] observation that, root: shoot dry matter ratio is lower in fertile than in infertile soil.

Table 1. Effects of pH &amp; MC on yield

	Total weight(g)	Total no. of tubers/fruits	Tubers with external wilt symptoms	Tubers without external wilt symptoms	No. of plants wilted	Fresh weight of roots	Dry weight of roots	Fresh weight of shoots	Dry weight of shoots	pH
Total weight(g)	1	.904**	-.019	.903**	-.428**	.697**	.721**	.863**	.803**	-.113
Total no. of tubers/fruits	.904**	1	-.072	1.000**	-.426**	.630**	.701**	.789**	.698**	-.044
Tubers with external wilt symptoms	-.019	-.072	1	-.100	.291*	.084	-.021	-.016	.009	.002
Tubers without external wilt symptoms	.903**	1.000**	-.100	1	-.435**	.626**	.700**	.788**	.696**	-.044
No. of plants wilted	-.428**	-.426**	.291*	-.435**	1	-.448**	-.459**	-.520**	-.507**	.116
Fresh weight of roots	.697**	.630**	.084	.626**	-.448**	1	.916**	.775**	.790**	-.101
Dry weight of roots	.721**	.701**	-.021	.700**	-.459**	.916**	1	.756**	.727**	-.120
Fresh weight of shoots	.863**	.789**	-.016	.788**	-.520**	.775**	.756**	1	.922**	-.077
Dry weight of shoots	.803**	.698**	.009	.696**	-.507**	.790**	.727**	.922**	1	-.079
Ph	-.113	-.044	.002	-.044	.116	-.101	-.120	-.077	-.079	1
Average MC	.103	.042	-.073	.045	-.079	-.057	-.024	.131	.168	1

\*\* 0.01 level of probability, \* 0.05 level of probability, - Negative relationship, + Positive relationship

### 3.2 Nutrient Content Analysis

Nutrient content analysis revealed that, BT treatments increased the soil pH slightly compared to the CM, MS and the control. In the soil, N found in decomposing organic matter may be converted into ammonium N ( $N_4H^+$ ) by soil microorganisms (bacteria and fungi) through mineralization [20]. This led to increased soil pH in BT treatment as compared to the other treatments and the control. Similarly, the BT treatment had higher Nitrogen content, organic carbon, calcium and potassium. At higher level of application, BT5292 had the highest amount of total nitrogen relative to the other amendments and the control. All the treatments except BT1908 increased the iron content in the soil relative to the initial amount. However, plots treated with Chalim™ recorded a higher amount of iron compared to the other treatments with BT1908 recording the lowest values. The amount of zinc, calcium, sodium and magnesium in the soil on plots treated with the various treatments was higher than the initial values although the treatments did not differ significantly ( $P>0.05$ ) from each other. Similarly, all the treatments used increased the amount of phosphorous in the soil although CM and MS treatments recorded higher values than the initial value before treatment. A high level of phosphorous is necessary for plants to produce good yield [21]. The various treatments reduced the potassium content in the soil compared to the initial amount with CM and the control recording lower values than the other treatments. The various treatments used did not differ in their moisture content although BT5292 had significantly higher moisture value. BT treatment, an organic manure that not only improves the soil physical, chemical and biological properties [22] but also improves the moisture holding capacity of soil, thus resulting in enhanced crop productivity along with better quality of crop produce [23]. MS200 recorded the least moisture content (Table 2).

Brassicaceous materials have also been reported to provide multiple benefits to agroecosystems necessary for the management of plant diseases [24], and have an impact on soil moisture and nitrogen capture [25]. Studies conducted on other parts of the world have revealed a significant association between the silicon and nitrogen on suppression of bacterial wilt disease [10, 26]. Although the other nutrients have not been directly associated with suppression of bacterial wilt disease, they may have an indirect role necessary for the suppression of the disease. Calcium has been found to be an important mineral for proper growth of tomato plants. Studies have revealed that plant parasitic nematodes (PPN) including root knot nematodes (RKN) causes wounds on the roots and tubers of susceptible hosts through which bacterial wilt (*Pseudomonas solanacearum*) penetrates resulting in greater yield loss in vegetable crops [27,28]. Plant parasitic nematodes severity may intensify in infertile soils with reduced soil moisture [29].

**Table 2. Effect of treatment on soil Physico-chemical properties**

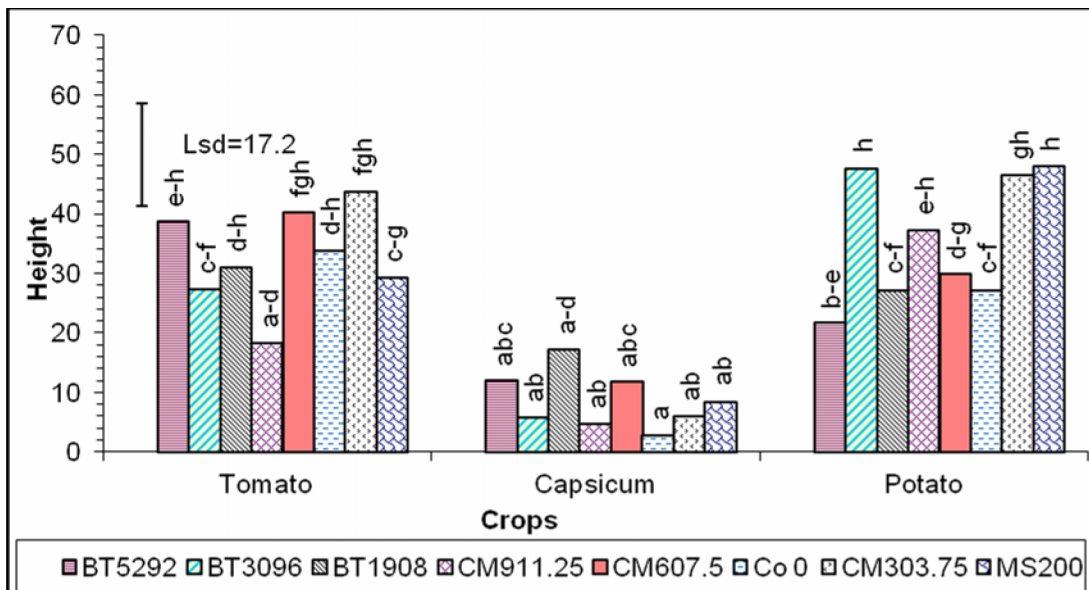
<b>Treatment</b>	<b>Soil PH</b>	<b>Exch.acidity me %</b>	<b>Total N %</b>	<b>C %</b>	<b>P ppm</b>	<b>K me%</b>	<b>Ca me %</b>	<b>Mg me%</b>	<b>Mn %</b>	<b>Cu ppm</b>	<b>Fe ppm</b>	<b>Zn ppm</b>	<b>Na me %</b>
BT 5292(1)	5.05	0.3	14	0.94	67	1.69	6.1	2.41	0.52	2.4	43.3	16.6	0.9
BT 3096(2)	5.04	0.2	0.14	0.94	69	1.77	6.1	2.21	0.52	2.4	45.2	14.5	0.92
BT 1908(3)	4.92	0.2	0.14	0.92	76	1.71	6.2	2.3	0.41	0.21	3.73	13.85	0.9
Chalim <sup>IM</sup> 911.25(4)	4.84	0.2	0.14	0.81	87	1.57	5.4	2.15	0.44	2.8	59.9	13.9	0.82
Chalim <sup>TM</sup> 607.5(5)	5.04	0.2	0.14	0.95	140	1.69	5.9	2.11	0.48	1.7	33.5	12.8	0.88
Control(0))	4.84	0.2	0.14	0.81	87	1.57	5.4	2.15	0.44	2.8	59.9	13.9	0.82
Chalim <sup>IM</sup> 303.75(5)	4.78	0.2	0.12	0.97	142	1.59	4.8	2.22	0.37	1.9	36.3	12	0.86
MS-200(8)	4.79	0.4	0.11	0.88	190	1.63	4.2	2.14	0.41	1.8	32.2	12.1	0.86
<b>Fertility results</b>	soil pH	exch.acidity me %	Total N %	N %	P ppm	K me%	Ca me %	Mg me%	Mn %	Cu ppm	iron ppm	Zinc ppm	sodium me %
<b>Initial</b>	4.79	0.7	0.15	0.78	66	1.93	5.6	2.09	1.21	2.4	16	10.9	0.12



### 3.3 Effect on Plant Growth Parameters

#### 3.3.1 Shoot height

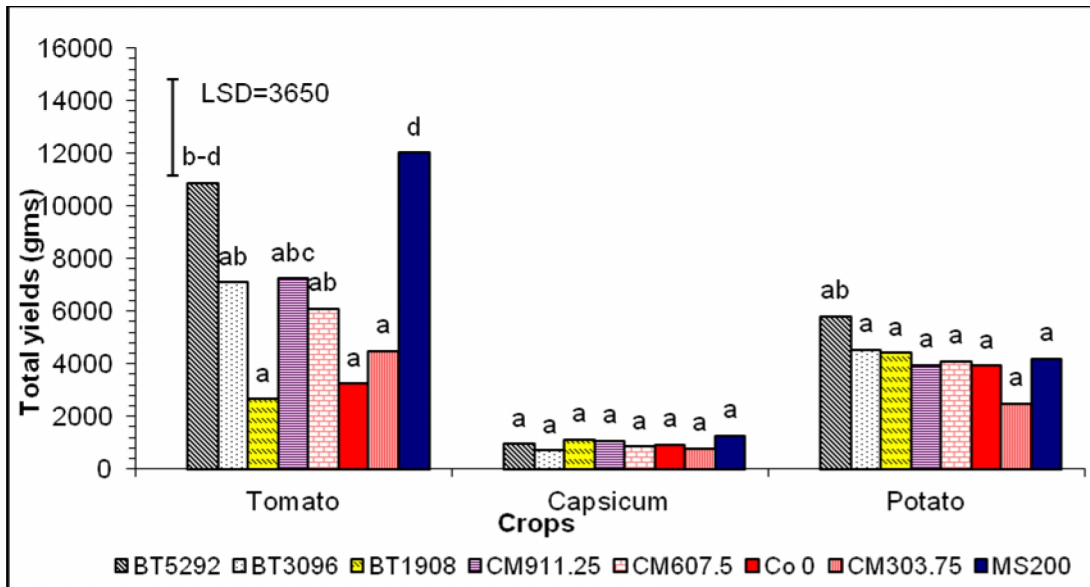
There was significant difference ( $P < 0.05$ ) in shoot height observed among the three crops at flowering stage during the first two seasons with potato being taller (38.3 and 25.1 cm) followed by tomato (26.5, 25.81 cm) and capsicum was the shortest (5.5, 10.79 cm) respectively as indicated in Fig. 1. Significant interaction effect ( $P < 0.05$ ) on the shoot height at flowering stage was established between the various treatments and the crops during the first season. During the second and third season the interaction effect was not significant ( $P > 0.05$ ). The various treatments tested were found to have varying effects on growth of the various test crops after 3 months. It was observed that the treatment effect on growth of the test crops was higher during the first and second seasons of growth, a trend that changed during the third season. Metham sodium was found to have generally increased plant height compared to the other treatments. This may be attributed to among other factors, its efficacy on reducing the bacterial wilt infection on the crops while on the field. The fact that Chalim™ was found to have higher shoots at lower rates of application, may be attributed to the fact that at higher rates of application, the plants may have been shocked by the treatment. It was, therefore expected that the higher rates of soil amendments would produce greater root biomass. However, [18] indicated that, in the responsive zone (i.e. concentration range where nutrients limit plant growth). Consequently, this could have weakened the plants to the extent that they became momentarily more susceptible to infection by *R. solanacearum*. Reductions in growth with increased Salinity might be due to the adjustment of osmotic potential [17, 30, 31]. Generally, NaCl stress, increased salinity lead to reduced plant growth (shoot height, shoot number, leaf number, and dry weight).



**Fig. 1. Effect of various treatments on shoot height in tomato, capsicum and potato crops**  
 Bars followed by similar letters are not significantly different. BT (Brassica tissue treatment in grams); CM (Chalim™ treatment in grams); MS (metham sodium treatment in ml) and Co 0 (control treatment).

### 3.3.2 Total yields

The various treatments differed significantly on their effect on the total yields. In tomato, the various treatments differed significantly ( $P < 0.05$ ) with plants grown on MS200 and BT5292 having significantly higher yields than the control. This was followed by plants grown on BT3096, CM911.25, CM607.5, CM303.75 that had higher yields that did not differ significantly from the control while those plants grown on BT1908, had lower yields though not significantly different from the control (Fig. 2). On the other hand, the treatments did not differ significantly on the total yield in capsicum. In potato, although there was no significant difference established among the various treatments, plants grown on BT5292, BT3096, BT1908, CM607.5 and MS200 had higher yields than the control. Plants grown on CM303.75 had lower yields that did not differ significantly from the control (Fig. 2). The various treatments differed significantly on their effect on the total yields as shown by Fig. 2. There was a significant difference on total yields where higher yields were realised in tomato and potato in plots treated with Brassica than in the other treatments. The plants' tolerance to bacterial wilt infection may have also been improved following soil amendment with organic matter from Brassica tissue. According to [17], well nourished plants are able to withstand disease infection and produce higher yields than the poorly nourished ones. Similarly, it has been observed that, increased yield and improved seed quality by receiving organic amendments is influenced by the residual effects of the amendments [32].



**Fig. 2. Effect of treatments on total yields of tomato, capsicum and potato during the second season**

Bars followed by similar letters are not significantly different BT (Brassica tissue treatment in grams); CM (Chalim™ treatment in grams); MS (metham sodium treatment in ml) and Co 0 (control treatment).

### 3.3.3 Dry root weight

The total dry root weight for each test plant per plot differed significantly ( $P < 0.05$ ) among the crops with tomato roots being heavier (113.2 g) than potato and capsicum (87.3 g and 42.7 g respectively). On the other hand, fresh shoot weight differed significantly ( $P < 0.05$ ) with

tomato recording higher mass (1223 g) compared to potato (1146 g) and capsicum (301 g) respectively as indicated by Table 1. According to [33] root growth and branching is favored in nutrient-rich environment and in the presence of hormones like auxins.

### **3.3.4 Number of haulms**

The number of haulms varied significantly ( $P < 0.05$ ) among the three crops with potato recording significantly ( $P < 0.05$ ) more haulms than the other crops, followed by tomato and capsicum for all the three season respectively (Table 3). Similarly, the various treatments were not significantly different ( $P > 0.05$ ) from each other on their effect on the number of haulms per plant at the end of the three seasons. Moreover the interaction effect between the treatments and the crops did not differ significantly throughout the three seasons. Results show that for the three season correlation coefficient remained high between number of haulms per plant and the percentage of nitrogen of potato tuber grew with increments of nutrition treatments in comparison with control treatment which is in agreement with the findings of [18].

**Table 3. The number of haulms on three test plants at the end of each season for the three seasons**

Crop	Season		
	1	2	3
Tomato	34.33b	30.54b	34.8b
Capsicum	18.0a	18.0a	18.0a
Potato	57.62c	51.5c	70.4c
P-value	0.001	0.001	0.001

*Means on the same column followed by similar letter(s) are not significantly different ( $P > 0.05$ ) according to Student-Newman-Keuls test.*

## **4. CONCLUSION**

The study results implies that, it is advisable for farmers to use *Brassica* at high levels of application (4355.56 kg/ha) and for farmers to moderately use Chalim™ (250 kg/ha) interchangeably with metham sodium (2000L/ha). This cut on fertilizer cost, reduces fertilizer residue effect and reduces soil pollution. *Brassica* tissue (BT5292) treatments showed positive response to test crops by increasing yields and were not only highly sensitive to RS at that rate but also, boosted plant growth, yields, moisture content and soil fertility. *Brassica* tissue (BT5292) should be applied in soils deficient in phosphorous, potassium, organic carbon and nitrogen as compared to the other treatments.

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## **COMPETING INTERESTS**

Authors have declared that no competing interests exist.

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