

Effect of different growing materials and irrigation frequency on some soil properties and yield of two chili cultivars grown in saline soil under greenhouse conditions

Thanyaluck Nontasri¹, Mallika Srisutham^{1*}, Thammared Chuasavathi¹ and Anan Polthanee²

¹ Department of Soil Sciences and Environment, Faculty of Agriculture, Khon Kaen University, 40002, Thailand

² Department of Agricultural, Extension and Systems of Agriculture, Faculty of Agriculture, Khon Kaen University, 40002, Thailand

ABSTRACT: Saline soil is one of limiting factors on crop production in northeastern Thailand. Therefore, the objective of this research was to investigate the effects of different growing materials application and irrigation frequency on some soil properties change, growth and yield of two chili cultivars grown under extreme soil salinity in greenhouse. A 4x4x2 factorial combination in randomized completely block design (RCBD) was laid out in the present experiment. The first factor consists of four growing materials applications; (1) coarse sand alone, (2) coarse sand+*M.calabura* dry leaves, (3) coarse sand+*M.calabura* dry leaves+polymer and (4) without growing materials application (control). The results revealed that exchangeable Na^+ and K^+ , including EC values change in soil with more or less, depending on the growing materials application. The application coarse sand+*M.calabura* dry leaves+polymer provided better balance of K^+ : Na^+ ratio in plants, and consequently promoted plants growth and yield of chili. The plants irrigated water twice in the morning and in the late afternoon with the equal amount of water tended to give higher fruit yield than that of the plants irrigated water once in the morning. The cultivar superhot produced significantly ($P \leq 0.05$) higher fresh fruit weight per plants (yield) than bird pepper due to greater of single fruit weight of the yield components in the present study.

Keywords: saline soil; exchangeable Na^+ ; exchangeable K^+ ; electrical conductivity; K^+ : Na^+ ratio; chili; fruit yield

Introduction

The problem of saline land is increasing in different parts of the world. It was found that more than 10% of the agricultural areas had salt problems, especially those with dry and semi-arid climates (Arunin, 1996). Salt affected soil in Northeast Thailand occupied about 2.84 million hectares and it has a potential to increase 3.1 million hectares in the future (Arunin, 1996). Saline soil is characterized by the presence of toxic levels of sodium and its chlorides and sulfates (Rajaravindran and Natarajan, 2012). Salinity generally creates the following conditions for plants: ionic stress, osmotic stress and disrupted homeostasis (Hernandez, 2018; Arunin, 1996). In addition, a combination of different morphological, physiological and biochemical effects may occur (Munns and Tester, 2008), negatively affecting nutrient acquisition, transpiration and the photosynthetic function of plants and resulting in stunted growth or potential plant loss. Remediation of salt – affected soil is significant for improving crop productivity. Addition of

* Corresponding author: smalli@kku.ac.th

Received: date; March 11, 2021 Accepted: date; June 15, 2021 Published: date; December 29, 2021

organic matter is an effective way to manage crops that are subjected to salt stress such as manure compost in tomato (Esteban et al., 2016), composed coir pith in sesame (Elayaraja and Sathiyamurthi, 2020). Plant residues are one of the most widely used as organic matter. Green manuring such as *Sesbania* spp. can be used reclamation of saline and sodic soils (Arunin, 1996). The application of organic matter to saline soil can improve surface soil fertility, soil structure and permeability, therefore, enhancing salt leaching, reducing surface evaporation, inhibiting salt accumulation in surface soils and releasing carbon dioxide during respiration and decomposition (Raychev et al., 2001). Moreover, the application of organic matter increases the quantity and quality of total organic carbon, nitrogen, phosphorus and other nutrients (Tejada et al., 2006; Zanuzzi et al., 2009; Yu et al., 2015). Manipulation of the distribution of soil with different textures (fine and coarse sand) could promote the removal of salts from the root zone and increase leaching efficiency (Berezniak et al., 2017). Polymer could store water and retain Cl^- and Na^+ in the soil solution and supporting K^+ resulted in an amended $\text{K}^+:\text{Na}^+$ balance in salinized plants (Dehkordi, 2017). Maintaining better irrigation regimes as found to alleviate the harmful effects of salinity (Singh et al., 2019). Chili is an important economic crop in Thailand, and it can be use as food and generate income for the smallholder famers because they can be grown in every region of Thailand. Chili contain a chemical called capsaicin that gives chili peppers a spicy taste. Most of the time, capsaicin accumulates in the white core membrane called "placenta" which Zahra (2015) reported that the 9-12 dS/m of salinity can increase the amount of capsaicin and the amount of proline, which acts as an antioxidant. Additional of compost gave the highest growth and yield of chili, followed by manure over without organic fertilizer (Anggraheni et al., 2019). However, in the extremely salty soil areas in the Northeast, there were no reports of crop yielding vegetables, especially chili. Therefore, the present of this research was to investigate the influence of different growing materials application and irrigation frequency on some soil properties change, growth and yield of two chili cultivars grown in saline soil under greenhouse conditions.

Materials and Methods

1. Soil samples area and experimental site

The soil used derived from a saline deposition at a depth of 0-30 cm in Du Yai village, Ban phai district, Khon Kaen province, Thailand. (latitude 16°03'06.2"N, altitude 102°40'14.2"E) (**Figure 1**). It was sandy loam in soil texture (64.62 % of sand, 29.6 % of silt and 5.78 of clay), soil group number 18 with 16.06 dS/m electrical conductivity (extreme saline soil) and contained total N, available P, exchangeable K^+ and Na^+ of 0.0035 %, 18.57 ppm, 167.42 ppm and 5,609.29 ppm, respectively. The soil was a 7.19 of pH, 1.93 gm cm^{-3} of bulk density, 15.93 % (w/w) of field capacity, 7.48 % (w/w) of permanent wilting point and 10.49 % (w/w) of soil moisture. The pot experiment was conducted in the greenhouse, Department of Soil Science and Environment, Faculty of Agriculture, Khon Kaen University (latitude 16°28'39.3"N, altitude 102°48'45.0"E).

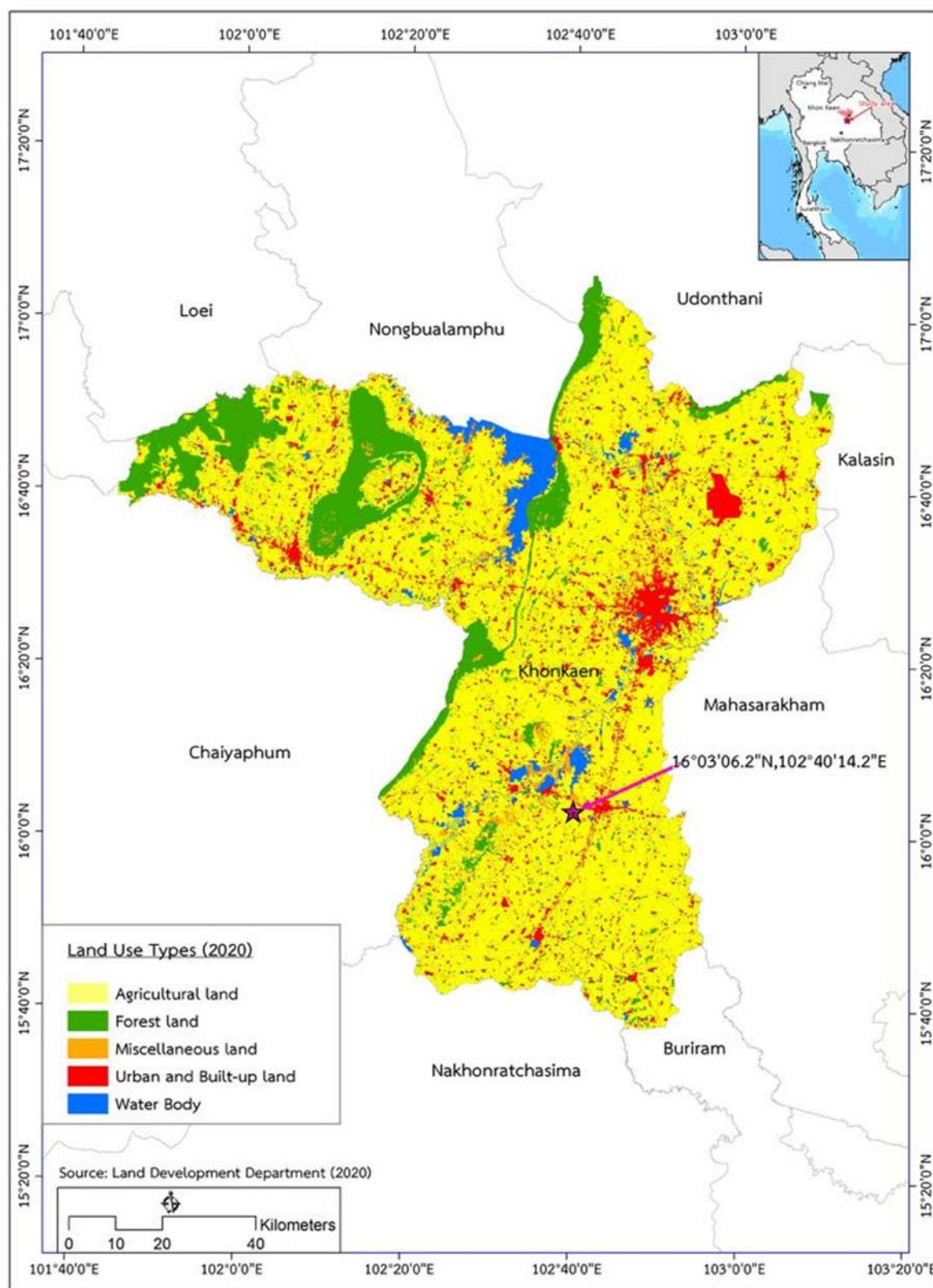


Figure 1 Saline soil samples area at Du Yai village, Ban phai district, Khon Kaen province, Thailand

Source: Land Development Department (2020)

Soil preparation and growing materials detail

The soil samples were air dried and filled 4 kg for each pot with size of 26 cm diameter and 18 cm height. The growing materials consist of *Muntingia calabura* L. dry leaves. It has a potential use as a green manure fertilizer where it grown near the experimental site. The *M. calabura* dry leaves contained of 0.99% total N, 0.005% total P and 0.42% total K. The other growing materials application were polymer and coarse sand. Polymer perform as a soil reformer to store more water in the roots zone and has a potential to alleviate salinity stress. While, coarse sand (250 μ m) used as a function of different soil texture for minimal salt accumulation surrounding the root zone.

Experimental design and treatments

The treatment structure was a 4x2x2 factorial arranged in a randomized complete block design (RCBD) with five replications. The first factor consists of three growing materials; coarse sand 500 g pot⁻¹, coarse sand 500 g pot⁻¹ combined with *M. Calabura* dry leaves 50 g pot⁻¹, coarse sand 500 g pot⁻¹ combined with *M. Calabura* dry leaves 50 g pot⁻¹ and polymer 5 g pot⁻¹ and no-growing material applied (control). The second factor comprises of two water irrigation frequency; one time (morning at 7.00-9.00 a.m. 200 ml), two times (morning at 7.00-9.00 a.m. 100 ml and afternoon 4.00-6.00 p.m. 100 ml). The third factor include two chili cultivars; bird pepper (*Capsicum frutescens* L.), superhot (*Capsicum annum* L.). The growing materials were placed to the soil with dimension of 10x10x10 cm (width x length x height) below soil surface and classified as inside growing materials zone (IGZ), and beyond segment of IGZ refer to outside growing materials zone (OGZ) (Figure 2).

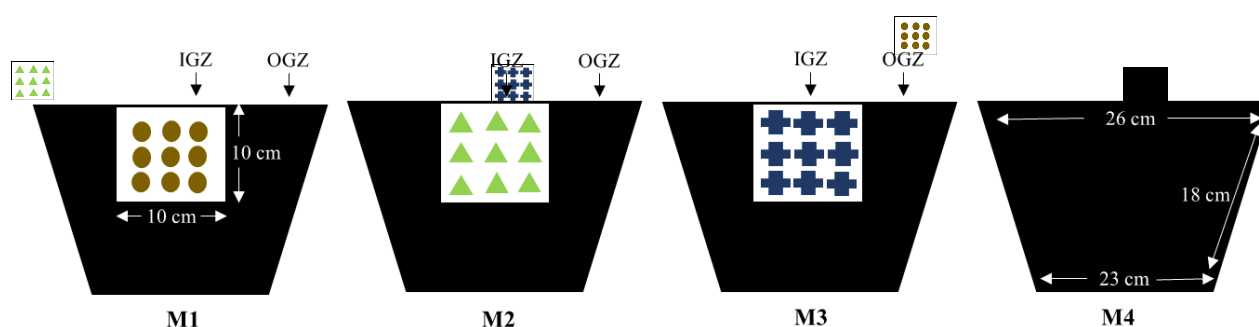


Figure 2 The different of growing materials application below soil surface; coarse sand (M1), coarse sand+*M. Calabura* (M2), coarse sand+*M. Calabura*+polymer (M3) and without growing materials application (control) (M4)

Crop management

Sixty days old of chili seedlings (80 plants) obtained from a nursery with well watering were transferred to the pots randomly filled with either growing materials or without the growing materials (control). Drip irrigation was used for watering every day all treatments. Chemical fertilizer formular 15-15-15 (N, P₂O, K₂O) was applied together with drip irrigated water 15 days interval (initiated at 15 days after transplanting) at rate of 1.66 g pot⁻¹, until harvest. The crop harvested 160 days old.

Measurement

Soil analysis

At final harvesting, above ground plant parts were removed from all pots. Soil were sampled from IGZ and OGZ of each pot, and roots were removed from the soil samples. The soil sampled were air dried and sift the soil through a 2 mm sieve for analysis. The exchangeable Na^+ and K^+ were analyzed using NH_4OAc (Soil analysis, 2000). Moreover, EC was analyzed using 1:1 of soil and water (Black, 1965) both IGZ and OGZ.

Growth characters and fruit yield

At the last time of harvest, chili fruits were removed from the plants and the fruits number of each pot were counted and fresh weighted, a summation of fresh fruit weight of each harvesting from the beginning until the last time of harvest was determined as fruit yield per plant. Irrespective plant growth, plant height was measured from the ground surface to the top of main stem. Thereafter, the plant was clipped at soil surface of each pot. The leaves were separated from stems. The leaves samples were measured leaf area with a leaf area meter (ACC-400, Hayasui Denken, Japan). The leaves and stems were oven dried at 80 °c for 48 h to determine the leaf dry weight. Roots were removed from the soil of each pot and then roots were washed by water and determine the surface area with WinRHIZO™ software 2017, thereafter root samples were oven dried at 80 °c for 48 h and their dry weight were recorded.

Sodium (Na^+) and potassium (K^+) concentration of plant parts

The leaves, stems and roots dry weight samples as mentioned above were analyzed for total Na^+ (%) and total K^+ (%) concentration (dry ashing method by Allen, 1974).

Data statistical analysis

ANOVA was used to compare the data and significant difference between mean values were measured by Least significant difference (LSD). Difference between means were designated as statistically significant when $P \leq 0.05$ probability level.

Results and discussion

In the present experiment, chili crop death at about 35 days after transplanting in the without growing materials (control) treatment due to the plants suffered from salt stress. Hence, the results and discussion of this experiment referred to only the rest of growing materials application treatments.

Soil property

Application of growing materials were significantly different in exchangeable Na^+ and K^+ , including electrical conductivity (EC) across irrigation frequency and cultivars both IGZ and OGZ (Table 1). Application of coarse sand combined with *M.calabura* and polymer demonstrated the maximum in exchangeable Na^+ and K^+ , as well as EC values of solid soil particle which analyzed both IGZ and OGZ. These results indicate that the Na^+ ion presence at low amount and leading to low EC values in the soil solution. This was associated with application of organic matter increased the sorption capacity of the growth medium (Esteban et al. 2016). The addition of organic materials increased soil EC were supported by the previous studies of Clark et al. (2007); Lee (2010) and Yu et al. (2015). Furthermore, application of organic matter increases the quantity and quality of total organic carbon, nitrogen, phosphorus, and other nutrients during decomposition process (Raychev et al., 2001; Yu et al., 2015). The chemical

composition of plant residue can differ considerably, depending on the plant species and state of plant growth (Yan and Schubert, 2000). Groundnut (*Arachis hypogaea*) stover, tamarind (*Tamarindus indica*) leaf litter, dipterocarp (*Dipterocarpus culatus tuber*) leaf litter and rice (*Oryza sativa*) straw gave N content of 20.09, 11.9, 6.0 and 4.9 g kg⁻¹ respectively (Xayavong, 2017). Amount of nutrients in rice straw at harvest are 5-8 kg N, 0.7-1.2 kg P, 12-17 kg K, 0.5-1 kg S, 3-4 kg Ca, 1-3 kg Mg and 40-70 kg Si per ton of straw on a dry weight basis (Dobermann and Witt, 2000). Nutrients content in groundnut stover after remove the pods at harvest are 16.5, 1.53 and 15.4 g kg⁻¹ for N, P and K on a dry weight basis, respectively (Konkhamdi et al., 2020). In the present experiment, total N, total P and total K contain of *M.calabura* dry leaf were about 0.99% N, 0.005% P and 0.42% K, respectively. The polymer application provided a K⁺ source and retained Na⁺ in the soil solution because of their high-water holding capacity (Dehkordi, 2017). In addition, application of coarse sand (diameter of ~500 µm) located under a drip irrigation were surrounded by finer texture soil reduced salt accumulation in the coarse segment of the manipulated soil (Berezniak et al., 2017). However, coarse sand applied in the present experiment with grain diameter of ~250 µm (small size) may have a little effect on salinity soil amendment in the IGZ.

For irrigation frequency, crop irrigated water one or two times was significantly different ($P \leq 0.01$) in exchangeable Na⁺ across growing materials and cultivars in IGZ, but there was no significant difference in OGZ at harvest (Table 1). The maximum exchangeable Na⁺ was observed when the crop was irrigated one time. This was probably due to irrigation water one time (200 ml) in the morning, wet soil period was shorter than split watering two times (100 ml+100 ml) in the morning and late afternoon. This results cause less Na⁺ leached to the soil solution.

Regarding cultivars (C), the exchangeable Na⁺ across growing materials and irrigation frequency was significantly different between the two cultivars in IGZ, but not a significant in OGZ (Table 1). The exchangeable Na⁺ was observed higher in the superhot cultivar in IGZ. This results indicate that the superhot uptake low amount of exchangeable Na⁺ as compared to bird pepper cultivar. R'him et al. (2012) reported that responses of pepper to salinity differ according to their genotypes. Salinity levels decreases the growth and yield parameters even though this decrease was cultivar-dependent the pepper.

Table 1 Exchangeable sodium (Na^+), exchangeable potassium (K^+) and electrical conductivity (EC) affected by different growing materials, irrigation frequency and cultivars in the inside of growing materials application zone (IGZ) and outside of growing materials application zone (OGZ) at harvest, pot experiment

Treatments	Na^+ (%)		K^+ (%)		EC (dS/m)	
	IGZ	OGZ	IGZ	OGZ	IGZ	OGZ
Growing materials (M)						
Coarse sand alone (M1)	0.22b	0.25b	0.02c	0.024c	2.83a	2.88ab
Coarse sand+ <i>M.Calabura</i> (M2)	0.19c	0.21c	0.03b	0.028b	2.16b	2.60b
Coarse sand+ <i>M.Calabura</i> +polymer (M3)	0.26a	0.30a	0.04a	0.039a	2.97a	3.16a
F-test	**	**	**	**	**	**
Irrigation frequency (I)						
One time (I1)	0.31a	0.26	0.04a	0.028b	3.44a	2.79
Two times (I2)	0.14b	0.25	0.02b	0.032a	1.87b	2.97
F-test	**	ns	**	**	**	ns
Cultivar (C)						
Bird pepper (C1)	0.20b	0.26	0.02b	0.03	2.44b	2.97
Superhot (C2)	0.25a	0.25	0.03a	0.03	2.87a	2.79
F-test	**	ns	**	ns	**	ns

Mean followed by the same letter at the same column were not significantly (ns), *, ** significantly at $P \leq 0.05$ and $P \leq 0.01$ probability level, respectively

In the present experiment, there was a significantly interaction between the effects of different growing materials application and irrigation frequency on exchangeable Na^+ and K^+ , as well as EC both IGZ and OGZ (Table 2). The application coarse sand decreased greater exchangeable Na^+ of soil by irrigation water one time, while application coarse sand combined with *M.calabura* decreased less exchangeable Na^+ than in IGZ. For EC, application coarse sand combined with *M.calabura* and polymer decreased greater EC of soil by irrigation water one time and EC decreased less when applied of coarse sand combined with *M.calabura* in IGZ (Table 2). Regarding exchangeable K^+ , application coarse sand combined with *M.calabura* reduced greater exchangeable K^+ of soil by irrigation one time. On the other hand, the lowest K^+ reduced when application coarse sand combined with *M.calabura* and polymer to the soil with one time irrigation in IGZ (Table 2).

Table 2 Interaction between growing materials (M) and irrigation frequency (I) of exchangeable sodium (Na^+), exchangeable potassium (K^+) and electrical conductivity (EC) inside of growing materials zone (IGZ) and outside of growing materials zone (OGZ) at harvest, pot experiment

Interaction	Na^+ (%)		K^+ (%)		EC (dS/m)	
	IGZ	OGZ	IGZ	OGZ	IGZ	OGZ
M1 × I1	0.34a	0.23d	0.031c	0.022e	3.67a	2.67cd
M1 × I2	0.10e	0.26c	0.016	0.025d	1.99cd	3.09bc
M2 × I1	0.23b	0.13f	0.039b	0.022e	2.71b	1.77e
M2 × I2	0.14d	0.30b	0.023d	0.034c	1.61d	3.43b
M3 × I1	0.35a	0.39a	0.043a	0.041a	3.94a	3.94a
M3 × I2	0.18c	0.20e	0.031c	0.036b	2.01c	2.39d
F-test	**	**	*	**	*	**

Mean followed by the same letter at the same column were significantly *, ** at $P \leq 0.05$ and $P \leq 0.01$ probability level, respectively; M1 = coarse sand, M2 = coarse sand + *M.calabura*, M3 = coarse sand + *M.calabura* + polymer, M4 = without growing materials (control) plants death before produce fruit yield, I1 = 1 time water irrigation, I2 = 2 times water irrigation

Na^+ and K^+ concentration in plant

Application of growing materials were significantly different ($P \leq 0.01$) in Na^+ concentration of leaves, stem and root across irrigation frequency and cultivars at harvest (**Table 3**). The minimum Na^+ concentrations of leaves was observed in the coarse sand application, while the lowest Na^+ of stem and roots were observed in the coarse sand combined *M.calabura* and polymer application. This was associated with low Na^+ content in soil solution of such treatment as mentioned earlier. In this experiment, the Na^+ accumulated in roots were less than those of leaves and stem. Hernandez et al. (2018) reported that increasing concentration of soil NaCl lead to increasing Na^+ accumulation in plants, which mainly occurred in the stem and leaf. In contrast, *Eucalyptus globulus* grown under NaCl and/or drought stress Na^+ accumulated greater in roots than that of leaves (Dehkordi, 2017).

Regarding irrigation frequency, the plants received irrigation water two times was significantly ($P \leq 0.01$) higher Na^+ concentration of leaves, stem and roots across growing materials and cultivars than that of irrigation water one time with the same amount (200 ml). This was probably due to irrigation water two times (split 100+100 ml) leached exchangeable Na^+ to soil solution greater than irrigation water one time, consequently the plants uptake and accumulated Na^+ higher in all plant parts. Irrespective cultivars, the superhot exhibited significant ($P \leq 0.01$) higher Na^+ concentration of leaves and roots, while the bird pepper showed higher Na^+ across growing materials and irrigation frequency of the stems (**Table 3**).

For K^+ , the application of growing materials was significantly different in K^+ concentration of leaves, stems and roots across irrigation frequency and cultivars (**Table 3**). The highest K^+ of leaves and stems were observed in application coarse sand combined *M.calabura* and polymer, while the maximum K^+ of roots was demonstrated in coarse sand application treatments. This was probably due to exchangeable K^+ content in soil higher in coarse sand combined *M.calabura* and polymer than the other treatments. In this study, the K^+ accumulated in roots were less than of leaves and stems. In contrast results was observed by Dehkordi (2017) who reported that K^+ concentration

accumulated in roots greater than in leaves of *Eucalyptus globulus* plants under NaCl and/or drought stress. Regarding irrigation frequency, the plants irrigated water one time gave significantly ($P \leq 0.01$) higher K^+ concentration across growing materials and cultivars of leaves and roots. While the plants irrigated water one time exhibited significantly ($P \leq 0.01$) higher K^+ of the stems (**Table 3**). Irrespective the cultivar, the bird pepper gave significantly ($P \leq 0.01$) higher K^+ concentration across growing materials and irrigation frequency of leaves and stems. while the superhot demonstrated significantly ($P \leq 0.01$) higher K^+ of the roots (**Table 3**). In the present study, in general, the K^+ concentration of leaves was higher than those of stems and roots for all treatments.

K^+ : Na^+ ratio in plant parts

In general, increasing Na^+ concentration in the growth medium affects the mineral nutrient composition in the plant tissue. Sodium accumulation impairs K^+ nutrition in salt-stressed plants. Therefore, maintenance of the K^+ : Na^+ ratio is an important guide in the assessment of salt resistance. Breeding and/or selecting crop with high K^+ : Na^+ ratio has been suggested to minimize crop loss under salt stress (Santa-Mania and Epstein, 2001). A plant's ability to selectively absorb K^+ in environments which have a large excess of Na^+ may be an important determinant of salt tolerance (Omielan et al., 1991). Maintenance of a high K^+ : Na^+ ratio is an important mechanism of salt resistance in the plants (Wakeel, 2013). The plants subjected to saline stress had an unfavorable K^+ : Na^+ ratio, mainly in the leaves and in the early stages of plant development. In some studies, a decrease in the K^+ : Na^+ ratio due to salinity has been reported (Wilson et al., 2002), and it has been established that low values of this ratio produce alterations in the cell membrane that affect K selectivity, as well as Na toxicity damage in leaves (Cramer et al., 1994; Alam, 1994).

In the present study, application of growing material was significantly different in K^+ : Na^+ ratio across irrigation frequency and cultivar of leaves, stems and roots (**Table 3**). The maximum K^+ : Na^+ ratio of the leaves and stems were obtained in the coarse sand combined *M. calabula* and polymer application, while the highest K^+ : Na^+ ratio of the roots was observed in the coarse sand application treatment. This was associated with such treatment had high K^+ concentration in leaves and stems in the present study. For irrigation frequency, the crop irrigated water one time was significantly higher K^+ : Na^+ ratio across growing materials and cultivars of the leaves, stems and roots (**Table 3**). This was probably due to low Na^+ concentration of the leaves, stems and roots presence in the irrigation water one time treatment. Regarding cultivar, the bird pepper cultivar was significantly ($P \leq 0.01$) higher K^+ : Na^+ ratio across growing materials and irrigation frequency of leaves, stems and roots than superhot cultivar (**Table 3**).

Table 3 Potassium and sodium concentration in leaves, stems and roots of chili as affected by different growing materials, irrigation frequency, and cultivars at harvest, pot experiment

Treatments	K ⁺ (%)			Na ⁺ (%)			K ⁺ : Na ⁺ ratio		
	Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root
Growing materials (M)									
Coarse sand alone (M1)	5.27c	4.23b	0.42a	1.12c	2.94a	0.90b	5.53b	1.44c	0.61a
Coarse sand+M. <i>Calabura</i> (M2)	6.06b	3.94c	0.40b	1.32b	2.16b	1.14a	4.78c	1.92b	0.39c
Coarse sand+M. <i>Calabura</i> +polymer (M3)	7.06a	4.42a	0.36c	1.38a	1.57c	0.89b	6.12a	2.82a	0.52b
F-test	**	**	**	**	**	**	**	**	**
Irrigation frequency (I)									
One time (I1)	6.52a	4.11b	0.41a	0.94b	2.03b	0.73b	7.26a	2.19a	0.65a
Two times (I2)	5.73b	4.28a	0.38b	1.60a	2.41a	1.21a	3.69b	1.93b	0.37b
F-test	**	**	**	**	**	**	**	**	**
Cultivar (C)									
Bird pepper (C1)	6.34a	4.95a	0.36b	1.07b	2.31a	0.69b	6.39a	2.29a	0.64a
Superhot (C2)	5.92b	3.44b	0.43a	1.48a	2.14b	1.26a	4.57b	1.83b	0.37b
F-test	**	**	**	**	**	**	**	**	**

Mean followed by the same letter at the same row were ** significantly at $P \leq 0.01$ probability level, M4 = without growing materials (control) plants death before produce fruit yield

In the present experiment, there was a significantly ($P \leq 0.01$) interaction between the effect of different growing materials and cultivar on Na⁺ and K⁺ concentration, including K⁺: Na⁺ ratio of leaves, stems and roots (**Table 4**). The superhot cultivar gave a significant ($P \leq 0.01$) higher Na⁺ concentration of leaves for all growing materials application treatments. However, the Na⁺ was observed greater decreased between two cultivars in the coarse sand combined *M.calabura* and polymer application. While, the Na was noticed less decreased in the coarse sand combined with *M.calabura* treatment. Regarding to stems, the bird pepper was significantly ($P \leq 0.01$) higher Na⁺ in the coarse sand or coarse sand combined with *M.calabura* and polymer application while the coarse sand combined with *M.calabura* gave significant ($P \leq 0.01$) higher Na⁺ in superhot cultivar.

For K⁺, superhot gave significant higher K⁺ concentration of leaves in coarse sand or coarse sand combined with *M.calabura* and polymer. On the other hand, bird pepper gave a significant higher K⁺ of leave in coarse sand combined with *M.calabura* application (**Table 4**). Regarding the stem, bird pepper gave a significant higher K⁺ in all application treatment. However, the K⁺ of stems decreased greater in the coarse sand combined *M.calabura* and polymer treatment (**Table 4**).

For K⁺: Na⁺ ratio, application coarse sand combined with *M.calabura* or coarse sand combined with *M.calabura* and polymer gave a significant ($P \leq 0.01$) higher K⁺: Na⁺ ratio in bird pepper than superhot, but not significant between the two cultivars when coarse sand application alone (**Table 4**).

Irrespective the stem, bird pepper gave a significant ($P \leq 0.01$) higher K⁺: Na⁺ ratio in all growing materials application treatments (**Table 4**). However, the K⁺: Na⁺ ratio of the stem decreased greater in the coarse sand combined *M.calabura* application treatment.

Table 4 Interaction between growing materials (M) and cultivars (C) of exchangeable sodium (Na^+), exchangeable potassium (K^+) and $\text{K}^+ : \text{Na}^+$ ratio of leaf, stem and root of chili at harvest, pot experiment

Interaction	K^+ (%)			Na^+ (%)			$\text{K}^+ : \text{Na}^+$ ratio		
	Leaf	Stem	Root	Leaf	Stem	Root	Leaf	Stem	Root
M1 × C1	5.01f	4.89b	0.42b	1.00d	3.17a	0.49f	5.47b	1.54d	0.86a
M1 × C2	5.53d	3.57d	0.43b	1.23c	2.70b	1.30a	5.59b	1.34f	0.36d
M2 × C1	6.98c	4.62c	0.37c	1.24c	1.88d	1.06d	5.84b	2.45c	0.36d
M2 × C2	5.14e	3.25f	0.43a	1.40b	2.45c	1.22c	3.73d	1.40e	0.42c
M3 × C1	7.03b	5.35a	0.30d	0.96d	1.87d	0.52e	7.85a	2.88a	0.70b
M3 × C2	7.08a	3.49e	0.43b	1.79a	1.27e	1.26b	4.39c	2.77b	0.34e
F-test	**	**	**	**	**	**	**	**	**

Mean followed by the same letter at the same column were ** significantly at $P \leq 0.01$ probability level.

M1 = coarse sand, M2 = coarse sand + *M.calabura*, M3 = coarse sand + *M.calabura* + polymer, M4 = without growing materials (control) plants death before produce fruit yield, C1 = Bird pepper, C2 = Superhot

Growth characters performance

Application of growing materials were significantly different in plant height, stem dry weight and root dry weight across irrigation frequency and cultivars, but there was no significantly different in leaf dry weight of chili at harvest (**Table 5**). The maximum plant height was observed in the coarse sand combined with *M.calabura* and polymer treatments while, stem dry weight and root dry weight were attained in the coarse sand combined with *M.calabura* treatments. However, most of growth characters did not significant difference between the coarse sand combined with *M.calabura* treatment and coarse sand combined with *M.calabura* and polymer treatments in the present study. Application of coarse sand combined with *M.calabura* and polymer promoted plant growth associated with the balance of the $\text{K}^+ : \text{Na}^+$ ratio in the leaves and stems of plants grown under extreme saline conditions. *M.calabura* and polymer application treatments may release of exchangeable K^+ adding to the soil via decomposition process and consequently increase K^+ uptake by plants. An optimal $\text{K}^+ : \text{Na}^+$ ratio may help to maintain of plant growth and yield development under saline conditions. The application organic amendments reduce the salt toxicity of soil by improving physical, chemical and biological properties, leading to enhanced plant growth and development were reported by many works (Shaaban et al., 2013; Wong et al., 2009; Cha-um and Kirdmanee, 2011; Esteban et al., 2016; Yu et al., 2015). In case of polymer application, polymer retained Cl^- and Na^+ in the soil solution because of their high water holding capacity, moreover, the exchangeable K^+ is one components of the polymer can help amended $\text{K}^+ : \text{Na}^+$ balance in saline plants (Dehkordi, 2017).

For irrigation frequency, the crop irrigated water one or two times had no significant effect on plant height, leaves dry weight, stem dry weight and root dry weight across growing material and cultivars (Table 1). The superhot gave a significantly higher in plant height, stem dry weight and root dry weight across growing materials and irrigation frequency than that of bird pepper (**Table 5**).

Table 5 Plant growth characters of chili as affected by different growing materials, irrigation frequency and cultivars at harvest, pot experiment

Treatments	Plant height	Leaf dry	Stem dry	Root dry
	(cm)	weight	weight	weight
		----- (gm plant ⁻¹)-----		
Growing materials (M)				
Coarse sand alone (M1)	50.50b	3.57	2.65b	0.57b
Coarse sand+M.Calabura (M2)	65.55a	4.02	4.35a	0.92a
Coarse sand+M.Calabura+polymer (M3)	67.20a	3.74	3.97a	0.91a
F-test	**	ns	**	**
Irrigation frequency (I)				
One time (I1)	60.43	3.44	3.68	0.83
Two times (I2)	61.73	4.11	3.64	0.77
F-test	ns	ns	ns	ns
Cultivar (C)				
Bird pepper (C1)	52.80b	4.06	2.46b	0.67b
Superhot (C2)	69.36a	3.49	4.85a	0.93a
F-test	**	ns	**	**
Interaction				
M × I	ns	ns	ns	ns
M × C	ns	ns	ns	ns
I × C	ns	ns	ns	ns
M × I × C	ns	ns	ns	ns

Mean followed by the same letter at the same column were not significantly (ns) and ** significantly at $P \leq 0.01$ probability level, M4 = without growing materials (control) plants death before produce fruit yield

Yield and yield components

Application of difference growing materials had significant effects on fresh fruit weight per plant (yield) and fruit number per plant across irrigation frequency and cultivars, but there was no significantly different in single fruit weight of chili (**Table 6**). The maximum fruit weight per plant and fruit number were obtained in the coarse sand combined with *M.calabura* dry leaves and polymer application treatments. However, there was no significantly different of fruit number and fresh fruit weight per plant between coarse sand combined with *M.calabura* dry leaves and coarse sand combined with *M.calabura* dry leaves and polymer treatments. This was associated with the two treatments promoted better growth characters than the other treatments. For irrigation frequency, there was no significantly different of the fruit number, fresh fruit weight per plant and single fruit weight across growing materials and cultivars between the two irrigation frequency (**Table 6**). In the present study, single fruit weight and fresh fruit weight per plant were significantly difference between the two cultivars, but there was not significantly different in fruit number per plant (**Table 6**). The highest fresh fruit weight per plant were attained in the superhot

cultivar. This was associated with the superhot give significant higher in single fruit weight than bird pepper cultivar. However, the bird pepper cultivar exhibited higher K^+ : Na^+ ratio balance than that of superhot in this study. This results seem to indicate that the bird pepper cultivar is better adapted to salinity stress than the superhot. In the present study, the plants grown without growing materials application (control) death before produced the fruit yield both cultivars. Hence, interpretation of the results in term of yield reduction compared to control of each cultivar could not calculated to evaluate the plants tolerant to salinity stress. The K^+ : Na^+ ratio demonstrated higher in the tolerant cultivar were reported by Cano et al. (1991) in tomato and Theerakulpisut and Phongngarm (2013) in rice.

Table 6 yield (fruit weight per plant) and yield components of chili as affected by different growing materials, irrigation frequency, and cultivars at harvest, pot experiment

Treatments	Fruit number (no.plant)	Fruit weight (gm plant)	Single fruit weight (gm)
Growing materials (M)			
Coarse sand alone (M1)	7.83b	8.98b	1.08
Coarse sand+M.Calabura (M2)	9.33ab	10.02ab	0.97
Coarse sand+M.Calabura+polymer (M3)	10.91a	14.97a	1.28
F-test	*	*	ns
Irrigation frequency (I)			
One time (I1)	9.88	10.14	1.06
Two times (I2)	8.83	12.50	1.16
F-test	ns	ns	ns
Cultivar (C)			
Bird pepper (C1)	7.72	2.84b	0.36b
Superhot (C2)	11.00	19.81a	1.86a
F-test	ns	**	**
Interaction			
M × I	ns	ns	ns
M × C	ns	ns	ns
I × C	ns	ns	ns
M × I × C	ns	ns	ns

Mean followed by the same letter at the same column were not significantly (ns), *, ** significantly at $P \leq 0.05$ and $P \leq 0.01$ probability level, respectively: M4 = without growing materials (control) plants death before produce fruit yield



Figure 3 Comparison chili growth of different growing materials application treatments at 160 days old

Remark: M1 = coarse sand, M2 = coarse sand+*M.calabura*, M3 = coarse sand+*M.calabura*+polymer, M4 = without growing materials (control) which plants death before produce fruit yield, I1 = Irrigation frequency one time, I2 = Irrigation frequency two times, C1 = Bird pepper



Figure 4 Comparison chili growth of different growing materials application treatments at 160 days old

Remark: M1 = coarse sand, M2 = coarse sand+M.calabura, M3 = coarse sand+M.calabura+polymer, M4 = without growing materials (control) which plants death before produce fruit yield, I1 = Irrigation frequency one time, I2 = Irrigation frequency two times, C2 = Superhot

Conclusion

The application of different growing materials caused changing in some soil chemical properties such as exchangeable Na^+ and K^+ , including EC of soil both in the inside and outside zone of application. The application of coarse sand combined with *M.calabura* dry leaves and polymer gave the maximum fresh fruit weight per plant (yield) of chili, but there was no significantly different with application of coarse sand combined with *M.calabura* dry leaves. This was associated with such treatments illustrated better balance maintaining of K^+ : Na^+ ratio in the plants. The crop irrigated water one or two times had no significant effect on fresh fruit weight per plant of chili. The superhot cultivar gave significant higher fresh fruit weight per plant than that of bird pepper cultivar.

References

- Alam, S.M. 1994. Nutrient uptake by plants under stress condition. P. 227–243. In: Pessarakli, M. (ed.) Handbook of plant and crop stress. Marcel Dekker, New York.
- Allen, S.E. 1974. Chemical Analysis of Ecological Materials, Blackwell, Oxford.
- Anggraheni, Y.G.D., F. Nuro, and Y.B. Paradisa. 2019. Effect of organic fertilizer on growth and yield of chili pepper. Conference: In Proceedings of the 3rd SATREPS Conference 22 November 2018. Bogor, Indonesia.
- Arunin, S. 1996. Salty soil in Thailand. Department of Land Development. Bangkok.
- Berezniak, A., A. Ben-Gal, Y. Mishael, and U. Nachshon. 2017. Manipulation of soil texture to remove salts from a drip-irrigated root zone. Vadose zone. 17: 1-11.
- Black, C.A. 1965. Method of soil analysis, Part 2, Chemical and microbiological properties, Number 9 in series Agronomy, American Society of Agronomy, Madison, Wisconsin USA. 914-926.
- Cano, E.A., M.C. Bolarin, F. Perez-Alfocia, and M. Caro. 1991. Effect of NaCl priming on increased salt tolerance in tomato. Journal of Horticultural Science. 66(5): 621-628.
- Cha-um, S., and C. Kirdmanee. 2011. Remediation of salt-affected soil by the addition of organic matter an investigation into improving glutinous rice productivity. Scientia Agricola. 68: 405-410.
- Clark, G.J., N. Dodgshun, P.W.G. Sale, and C. Tang. 2007. Changes in chemical and biological properties of a sodic clay subsoil with addition of organic amendments. Soil Biology and Biochemistry. 39: 2806–2817.
- Cramer, G.R., G.J. Alberico, and C. Schmidt. 1994. Salt tolerance is not associated with the sodium accumulation of two maize hybrids. Australian Journal of Plant Physiology. 21: 675–692.
- Dehkordi, D.K. 2017. Effect of superabsorbent polymer on salt and drought resistance of *Eucalyptus globulus*. Applied Ecology and Environmental Research. 15(4): 1791-1802.
- Dobermann, A., and C. Witt. 2000. The potential impact of crop intensification on carbon and nitrogen cycling in intensive rice systems, pp. 1-25. In Proceedings of the workshop on carbon and nitrogen dynamics in flooded soils, Annual Conference 19-22 April 1999. Los Banos, Philippines.
- Elayaraja, D., and S. Sathiyamurthi. 2020. Influence of organic manures and micronutrients fertilization on the soil properties and yield of sesame (*Sesamum indicum* L.) in coastal saline soil. Indian Journal. of Agricultural Research. 54(1): 89-94.
- Esteban, W., P. Pacheco, L. Tapia, and E. Bastias. 2016. Remediation of salt and boron-affected soil by addition of organic matter: an investigation into improving tomato plant productivity. DESIA (Chile). 34: 25-32.
- Hernandez, M.A.L., D.A. Bernal, and G.C. Cárdenas. 2018. Improvement of saline soils with *Vicia sativa* L. from a semiarid region. Bragantia. 77(1): 1-9.

- Konkhamdi, S., A. Polthanee, and M. Srisuthum. 2019. Legume crops rotation with rice production in rainy season. Research Report in 2019, Khon Kaen University. Khon Kaen.
- Lee, J. 2010. Effect of application methods of organic fertilizer on growth, soil chemical properties and microbial densities in organic bulb onion production. *Scientia Horticulture* (Amsterdam). 24(3): 299–305.
- Munns, R., and M. Tester. 2008. Mechanisms of salinity tolerance. *Annual Review of Plant Biology*. 59: 651–681.
- Omielan, J.A., E. Epstein, and J. Dvořák. 1991. Salt tolerance and ionic relations of wheat as affected by individual chromosomes of salt-tolerant *Lophopyrum elongatum*. *Genome* 34: 961–974.
- Rajaravindran, M., and S. Natarajan. 2012. Effects of salinity stress on growth and antioxidant enzymes of the halophyte *Sesuvium portulacastrum*. *International Journal Research Plant Science*. 2: 23–28.
- Raychev, T., S. Popandova, J. Józefaciuk, M. Hajnos, and Z. Sokolowska. 2001. Physicochemical reclamation of saline soils using coal powder. *International Agrophysics*. 15(1): 51–54.
- R'him, T., R. Ilahy, I. Tlili, K. Nouri, and J. Hager. 2012. The effect of salinity on some growth and yield parameters of three pepper (*capsicum annuum* L.) varieties grown in Tunisia. *Global Science Books*. 7(1): 27–31.
- Santa-Maria, G.E., and E. Epstein. 2001. Potassium/sodium selectivity in wheat and the amphiploid cross wheat x *Lophopyrum elongatum*. *Plant Science*. 160: 523–534.
- Shaaban, M., M. Abid, and R.A.I.A. Shanab. 2013. Amelioration of salt affected soils in rice paddy system by application of organic and inorganic amendments. *Plant Soil Environment*. 59(5): 227–233.
- Singh, J., S.K. Verma, J.N. Bhatia, and L. Raj. 2019. Effect of different soil moisture regimes and salinity level on growth and yield in mustard. *Indian Journal of Agricultural Research*. 53: 488–491.
- Soil Analysis. 2000. Soil analysis handbook of reference methods. Soil and Plant Analysis Council, Inc. CRC Press. Washington, D.C.
- Tejada, M., C. García, J.L. González, and M.T. Hernández. 2006. Use of organic amendment as a strategy for saline soil remediation: influence on the physical, chemical and biological properties of soil. *Soil Biology and Biochemistry*. 38: 1413–1421.
- Theerakulpisut, P., and S. Phongngarm. 2013. Alleviation of adverse effects of salt stress on rice seedlings by exogenous trehalose. *Asian Journal of Crop Science*. 5(4): 405–415.
- Wakeel, A. 2013. Potassium–sodium interactions in soil and plant under saline-sodic conditions. *Journal of Plant Nutrition and Soil Science*. 176: 344–354.
- Wilson, C., J.J. Read, and E. Aboukasssem. 2002. Effect of mixed-salt salinity on growth and ion relations of a quinoa and a wheat variety. *Journal of Plant Nutrition*. 25(12): 2689–2704.
- Wong, V.N., R.C. Dalal, and R.S. Greene. 2009. Carbon dynamics of sodic and saline soils following gypsum and organic material additions: a laboratory incubation. *Applied Soil Ecology*. 41: 29–40.
- Xayavong, S. 2017. Changes in soil chemical properties affect plant growth under 20-year applications of contrasting quality organic residues with and without chemical fertilizer. M.S. Thesis, Khon Kaen University, Khon Kaen.
- Yan, F., and S. Schubert. 2000. Soil pH changes after application of plant shoot materials of faba bean and wheat. *Plant and Soil*. 220(1/2): 279–287.
- Yu, Y., J. Liu, C. Liu, S. Zong, and Z. Lu. 2015. Effect of organic materials on the chemical properties of saline soil in the Yellow River Delta of China. *Frontiers of Earth Science*. 9: 259–267.
- Zanuzzi, A., J.M. Arocena, J.M.V. Mourik, and A.F. Cano. 2009. Amendments with organic and industrial wastes stimulate soil formation in mine tailings as revealed by micromorphology. *Geoderma*. 154(1–2): 69–75.
- Zahra, N., A. Hattab, A.A. Saadon, and A.E.K. Ekhlas. 2015. Effect of salinity stress on *Capsicum annuum* callus growth, regeneration and callus content of capsaicin, phenylalanine, proline and ascorbic acid. *Journal of Life Sciences*. 9: 304–310.