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Effect of planting space and shoot pruning on the occurrence of thrips, fruit yield and quality traits of sweet pepper (*Capsicum annum* L.) under greenhouse conditions

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Abstract
The effect of planting space and shoot pruning was investigated in sweet pepper (*Capsicum annuum* L.) during summer 2018 in Tsukuba Japan. Two spacing (40 cm and 70cm between rows) and three pruning levels (No pruning, 2 stems, and 4 stems) were adopted. The experiment was laid as a randomized complete block design with two replications. Data collected were thrips occurrence, the number and weight of marketable and unmarketable fruits. More number of thrips was observed on the none-pruned plants while less thrips was observed on the plants with four stems. The narrower spacing gave more yields during early period of harvesting season despite the higher thrips occurrence. The narrower spacing with none-pruned practice could be adoptable if early harvest for a short period is targeted. However, to sustain harvest for consistence supply, the plants with four stems should be adopted due to better yield with minimal thrips occurrence.

Keywords: Shoot pruning, planting space, thrips occurrence, fruit quality, marketable yield

Introduction
Sweet pepper (*Capsicum annuum* L.) is one of the most widely grown fruit vegetables. The crop has gained popularity by consumers and producers in Tanzania in recent years (FAOSTAT 2018) [1]. The fruit can be eaten raw in salad or cooked as flavor for soup, and stew. It is considered as a high value crop rich in vitamin A, vitamin B, vitamin C and minerals such as Ca, P, K and Fe (Malik *et al.*, 2011; Maboko *et al.*, 2012) [2, 3]. Sweet pepper is grown in both greenhouse and open field and the yield is affected by abiotic and biotic factors. The biotic factors can exacerbate susceptibility of plant to insect pests and diseases leading to qualitative and quantitative loss in sweet pepper production. Sweet pepper plants under greenhouse conditions are known to be susceptible to a number of insects and pests, including aphids (*Aphis gossypii* Glover**)**, broad mites (*Polyphagotarsonemus latus* Banks), greenhouse whiteflies (*Bemesia tabaci* Gennadius*)*, western flower thrips (*Franliniella occindentalis* Pergande) andtwo spotted spider mites (*Tetranychus urticae* Koch*)*. Cultural practices such as planting space and shoot pruning have direct effects on insect pest occurrence, yield and quality of fruits which are the determinant of price in the market (Seifi *et al.*, 2012) [4]. Planting space determines plant population. It is known to affect plant growth and yield under greenhouse production (Verheij and Verwer, 1971; Guo *et al.*, 1991; Cebula, 1995; Lorenzo and Castilla, 1995; Jovicich *et al.*, 1999) [5, 6, 7, 8, 9]. The yield per unit area is likely to increase up to a certain point as plant density increases and then declines (Akintoye *et al.* 2009) [10]. High plant density gives early yield with reduced fruit size and weight (Cebula 1995; Jovicich *et al.*, 1999) [7, 9]. Traditionally sweet peppers grown in open field under rain-fed conditions were not pruned in Tanzania, which could result in shortening the harvest interval and making cultural practice such as weeding and spraying difficult. Proper pruning facilitates early fruit set, maturity and uniformity. Pruning technique improves air circulation within the canopy, and reduces foliar diseases and insect pest (Zrubecz and Toth) [11]. Pruning of stem by retaining reasonable number leads to the increased yield and quality (Jovicich *et al.*, 2004; Maboko *et al.*, 2012) [12, 2]. Pruning involves selective removal of excess branches and leaves which allows light penetration and interception for efficient dry mater production and partition to the plant. None-pruned plants develop dense foliage that increases the risk of fruit damage by thrips.

The abundance and spatial distribution of the adult thrips is reportedly dependent on the conditions of the habitat, with some areas having higher densities while others having low density (Ribeiro *Jr et al.*, 2009) [13]. The habitat which is characterized by dense foliage and flowers favors feeding and oviposition of sucking insect pest. The movement of the thrips within the field or to the areas with weedy plants may be due to the presence of plants at flowering stage, as flowers attract these insects (Norris and Kogan, 2005 [14]. Despite the vital roles played by shoot pruning and planting space, the information on the optimum combination between shoot pruning and planting space in relation to thrips occurrence, fruit yield and quality is scanty in the country. Therefore the objective of this study was to examine the optimal planting space and pruning technique to increase yield and quality of sweet pepper fruits.

Materials and methods

The experiment was conducted in a plastic greenhouse located in Annex field at Tsukuba International Center in Ibaraki prefecture from 26thApril to 5th August 2018 as a part of technical trainingcurriculum. Sweet pepper variety "Kyo-Hikari" (Takii & Co., Ltd., Japan) was planted in a randomized complete block design (RCBD) with two replications. The six treatments were the combination of two plant spacing (40cm (S40) and 70cm (S70) between plants) and three shoot pruning methods (none pruning (P0), 2 stems (P2), and 4 stems (P4)). The distance between rows was 1.6 m for all the treatments.

Field was prepared on 26th April and compound fertilizer (15:15:15% of N:P:K) was applied as basal to supply 10 g each of NPK per square meter. The seedlings were purchased from a private nursery and transplanted on 2nd May when they were at the first flowering stage approximately 45 cm tall. The transplanted bed was covered with rice straws to conserve soil moisture and staking was done to support each plant. Pruning was done according to the treatments throughout the growth of plants (Photo 1).Two and four stems were maintained whereby any lateral shoots appeared were pinched off. The first top dressing was done three weeks after transplanting using the compound fertilizer at 2.5g each of NPK per square meter. The other two top dressings were applied with three week interval at the same rate as the first top dressing. Two insecticides (Malathion and Permethrin) were sprayed when occurrence of aphids increased on 25th June and 1stJuly.

Pepper fruits were harvested twice a week when the fruits were at mature green stage having 8cm in length and above. The harvested fruits were graded based on damage, shape, length and weight. They were then classified into marketable and un-marketable (i.e. malformed, damaged by thrips and blossom end rot).

Photo 1: Different level of pruning, (left: none-pruned, middle: two stems and right: four stems method)

The observation of thrips on leaves and flowers started on 16thMay two weeks after transplanting and continued at 15 day intervals to the end of the experiment. The observation was done in the evening from six leaves divided to apical, middle and basal positions of branches and three flowers from each of two plants selected at the middle of each experimental plot. Three consecutive beats were performed on both leaves and flowers. A white pepper A4 size was used for collection and counting the total number of falling insects after beating (Photo 2). The methodology was adapted with minor modification from Moreira *et al.* (2017) [15]. Similarly for monitoring of insect population, sticky cards (yellow and blue) were hanged on each plot (Photo 3).

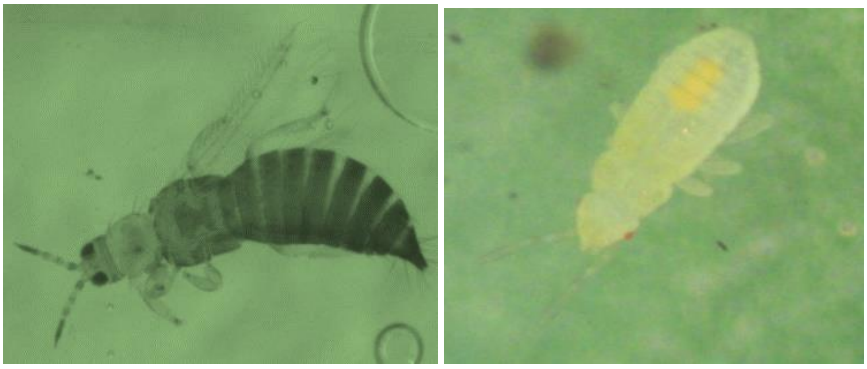

Photo 2: The adult (left) and nymph (right) stage of thrips observed

Photo 3: Sticky cards for insect monitoring

Results and Discussion

Thrips occurrence

About 16 thrips species have been reported to occur on *Capsicum* (Bae *et al.*, 2015; Talekar, 1991) [16, 17]. *Frankliniella occidentalis* (Pergande) is the most common thrips species on Capsicum growing areas (Tommasini and Maini, 1995) [18]. However three types of thrips are commonly found in Japan especially Ibaraki area namely *Thrips palmi* (Karny), *Frankliniella intosa* (Trybom), *Frankliniella occidentalis* (Pergande). They are known to affect flowers, leaf and fruits. This experiment aimed to study the occurrence of total thrips on sweet pepper plant and their effects on fruits regardless of their composition.

The results from current study depicted that pruning techniques have a significant effect on the number of thrips collected per plant (Fig.1).Significantly more numbers of thrips were collected on none-pruned plants (S40P0 and S70P0) as compared to pruned plants (S40P2, S40P4, S70P2, and S70P4). Furthermore the observation confirmed that thrips were present throughout the growing season in both pruned and none-pruned plants with two peaks on 30th May and 23rd June. The lowest number in the both peaks was recorded for plants pruned to four stem within 70cm. None-pruned stem provide favourable niche for thrips since crowded conditions favours oviposition and multiplication due to assured food base. These insects prefer enclosed areas such as flowers, underside of the fruits calyx and in newly opening leaves (Weintraub 2007; Maharijaya and Vosman, 2011) [19, 20]. Most sap sucking insects including thrips are attracted by new foliage as they feed on the growing apex, developing shoots and foliage which in turn affect their population distribution on plant parts. However the older and folded leaves could also give the feeding site (Paibomesai *et al.*, 2013; Zereabruk, 2017) [21, 22]. On the other hand pruning modifies the canopy and foliage composition which in turn could interfere the habitat for pests and hence less number.The number could increase as new flowers are set. During this experiment two peaks of high dense population were observed which coincides with flowering stage. This observation agree with earlier findings by Childers and Brecht (1996) [23]; de Kogel and Koschier (2003) [24]; Ssemwogerere *et al.* (2013) [25]. Who reported the occurrence of *F. occidentalis* in the presence of plant at flowering stage.

Comparing two planting space, the results indicated that more thrips were observed in the narrower planting space (S40) than the wider planting space (S70).

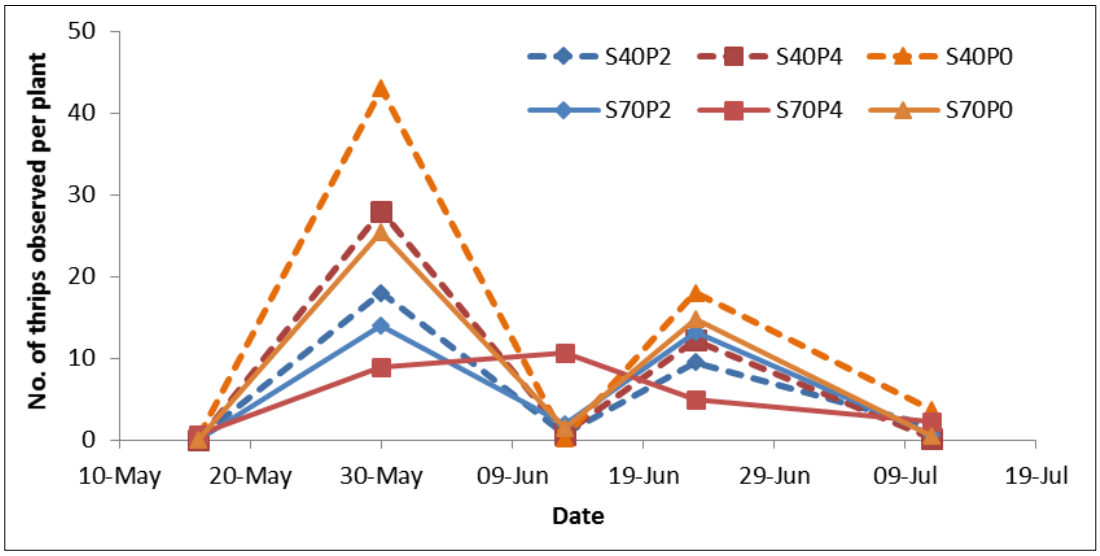

Fig 1: Comparison on number of thrips observed in different treatments

Fruit yield

Table 1 showed that the wide space (S70) had more fruit weight per plant than the narrow space (S40). In terms of pruning technique, none-pruned plants (P0) gave higher yield followed by four stem pruning (P4) in both planting spaces. On the other hand, the lower yield was observed in the wide space. The cumulative marketable yield (Fig. 2) showed that the narrow space (S40) had more yield than the wide space (S70) throughout the experiment period. Irrespective of planting spaces, none-pruned plants produced more yield, followed by four stem method and, then, two stem method. Jovicich *et al.* (1999) [9]; Thakur *et al.* (2018) [26] reported higher marketable yields from sweet pepper plants pruned to four stems. The reduced number of branches by pruning improves light interception, fruit set and fruit quality (Resh 1996; Thakur *et al.*, 2018) [26, 27]. The findings from previous research by (Aminifard *et al.*, 2010 [28]; Cebula 1995 [7]; Jovicich *et al.*, 2004 [12]: Lorenzo and Castilla 1995) [29] reported an increase in yield of pepper at higher plant population per unit area. This could be attributed by an increased number of plants as well as stem per unit area which contribute to more number of fruits per area.

Table 1: Weight of fruits harvested from May 29th to July 31th

Treatment	Marketable fruits (gplant^{-1})	Un-marketable fruits(gplant^{-1})		Marketability (%)	Yield (g m^{-2})
		Malformed	Blossom end rot		
S40P2	1,656.6 b	8.8 a	371.5 a	81.3 a	2,588 ab
S40P4	1,867.8 b	0.0 a	408.8 a	82.0 a	2,918 ab
S40P0	2,068.3 ab	11.5 a	266.0 a	88.0 a	3,231 a
S70P2	2,114.4 ab	0.0 a	724.0 a	74.5 a	1,886 b
S70P4	2,342.5 ab	6.4 a	594.4 a	80.0 a	2,090 ab
S70P0	3,121.1 a	7.5 a	337.8 a	90.5 a	2,784 ab

Means followed by the same letter within each column are not significantly different at the 5% level in Tukey's HSD test.

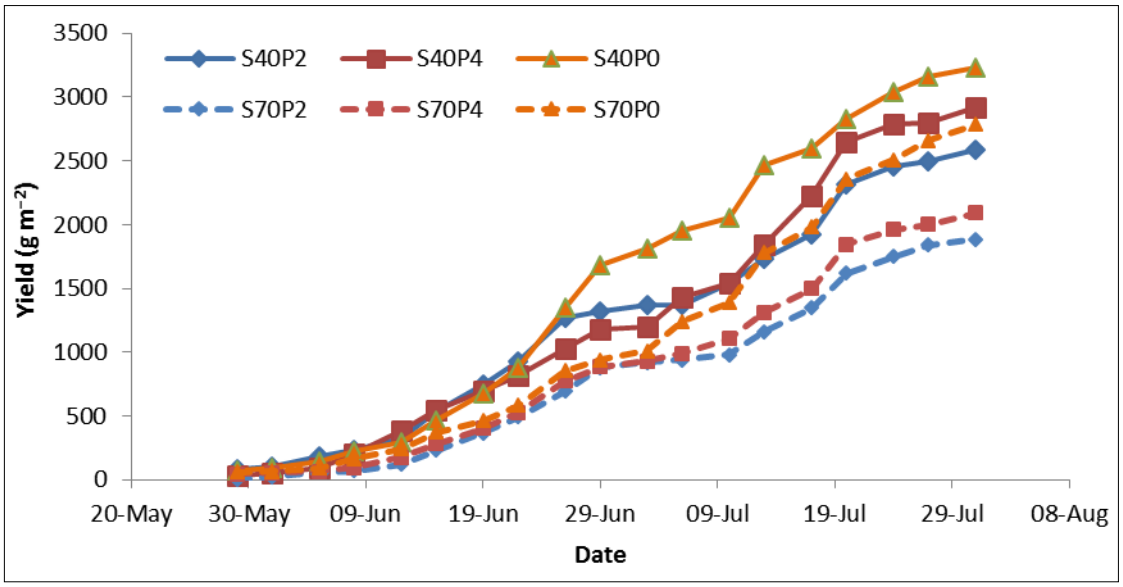

Fig 2: Change of cumulative yield in different planting spaces and pruning methods

Fruit quality

Despite the presence of thrips observed during the growing season, no fruit has been classified as unmarketable due to thrips attack. Some fruits were deemed to be unmarketable due to other reasons such as blossom end rot and malformed (Photo 4). There was not significant difference in marketability among the treatments (Table 2).

The blossom end rot (BER) disorder was also observed in this experiment. Probable reason for the disorder to appear was due to increased temperature above 30°C and more vegetative growth of plant observed during the experiment. The known cause of this disorder is an inadequate amount of Ca in soil, unfavourable moisture, fluctuation in moisture regime, low soluble soil calcium (Ca), and high temperature (Matthew *et al.*, 2004) [30]. The situation was rectified on 30th May by covering the plastic greenhouse with fabric sheet to regulate temperature and spraying of Ca solution on plant leaves on 9th June and slaked lime (hydrated lime) was incorporated in soil on 30th June. Sergio *et al.* (2013) [31] suggested that spraying plants with Ca^{2+} reduces the risk of BER development.Plant growth and stem structure were affected by pruning technique Photo 5, where none-pruned plants grow more horizontal canopy while plants pruned to two and four stems grow more vertically. This means if the plants were left to grow to the end of experiment more harvest could have been obtained from pruned stem due to increased overall fruit set than non-pruned stem.

Photo 4: Un-marketable fruits: malformed (left) and blossom end rot (right)

Photo 5: Appearance of plants at 94 days after transplanting

Conclusion and Recommendation

This study provided the useful information on the effect of planting space and pruning on yield and quality of sweet pepper grown inside plastic greenhouse. The results showed that planting space and pruning technique played an important role on thrips occurrence and yield. More thrips were observed on none-pruned plants and less on plants pruned up to four stems. On the other hand narrow spacing (S40) gave more yields per unit area as compared to the wide spacing (S70).

Therefore sweet pepper for short term growing in rain fed cultivation and harvesting for seasonal market, the narrower spacing with none-pruned practice can be adopted. However for continuous harvest and consistence supply, pruning technique should be adopted due to better yield and minimal thripsoccurrence. This should be coupled with placement of sticky cards both yellow and blue colour to monitor insect population and minimize damage.

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