HORTIN II Co Innovation Programme

Towards cost effective, high quality value chains

Effect of plant balancing on the growth and yield of two sweet pepper varieties harvested yellow, green and red

HORTIN-II Reasearch Report nr. 24

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The purpose of the HORTIN-II programme is to contribute to the development of cost effective high quality value chains for vegetables and fruits. Among others this can be achieved when technology development takes place in close collaboration between public institutions, farmers and private companies.

On the Indonesian side the programme is carried out by the Indonesian Centre for Horticultural Research and Development **(ICHORD),** Jakarta, with the Indonesian Vegetable Research Institute **(IVEGRI)**, Lembang, and the Indonesian Centre for Agricultural Postharvest Research and Development **(ICAPRD)** in Bogor.

In the Netherlands the Agricultural Economics Research Institute **(AEI)**, Den Haag, the Agrotechnology and Food Sciences Group **(ASFG)**, Wageningen, Applied Plant Research **(APR)**, Lelystad, and WUR-Greenhouse Horticulture **(WUR-GH)**, Bleiswijk, all partners in Wageningen University and Research centre, are involved in the programme.

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CONTENTS

Abstract

Two experiments to determine the effect of three system of plant balancing between the vegetative and generative period during one season period on the growth and yield of two sweet pepper varieties harvested green and colour were conducted at the field experiment of Indonesian Vegetable Research Institute (IVEGRI), Lembang (1250 m asl.) and at a farmer's farm in Pasirlangu, Cisarua, West Java from May 2008 to March 2009. Three plant balancing system treatments were involved i.e. (1) plant balancing between vegetative and generative system A, (2) plant balancing between vegetative and generative system B, and (3) plant balancing between vegetative and generative system C. In the two experiments, three varieties were involved i.e. (1) Sunny (harvested yellow), (2) Spider (harvested red), and (3) Spider (harvested green). The treatment combinations were arranged in a randomized complete block design with three replications. The results indicated that plant balancing system did not significantly affect total yield and yield of fruit in class >200 g, although in terms of growth which was indicated by the plant height, the plant balancing system affected significantly on the three varieties, and the plants using the plant balancing between vegetative and generative system C were lower than those of plants using the plant balancing between vegetative and generative system A and B. The total yields and total number of fruit of Spider variety harvested green were significantly higher than those of Spider variety harvested red and Sunny (yellow), however the yield and fruit number of fruit in class > 200 g of Spider variety harvested green were significantly lower than those of Spider variety harvested red and Sunny (yellow). Differences in total yields were observed between experiments and in general the total yields of Experiment 1 conducted in the wood-metal plastic house at IVEGRI were higher than those of Experiment 2 conducted in the bamboo plastic house at a farmer's farm in Pasirlangu.

Keywords: *Capsicum annuum* var. grosum; Plant balancing system; Variety

1 INTRODUCTION

In Indonesia, sweet pepper (*Capsicum annuum* L.) is one of the important vegetables produced under protected cultivation. Most of the sweet peppers are cultivated by farmers using simple plastic houses, made mostly from bamboo. In general, the productivity of sweet pepper is constrained by the adverse effects of high temperatures on fruit set, and detrimental influence of low temperatures on fruit shape. For high yields of good quality fruit, the mean air temperatures of 21-23^{0}C are optimal during vegetative growth, followed by 21^{0}C during the fruit growth period. In Indonesia, the sweet pepper plant is suitable grown in the highland area where the air temperatures are relatively low, about 16-25^{0}C. Sweet pepper production using protected cultivation system is based on indeterminate cultivars in which the plants continually develop and grow from the new meristems that produce new stems, leaves, flowers and fruit. Indeterminate cultivars require constant pruning to manage their growth. In order to optimize the yields of sweet pepper, a balance between vegetative (leaves and stems) and generative (flowers and fruit) growth must be established and maintained. Harvesting green fruit in the sweet pepper cultivation is one of the methods in order to stimulate the growth and fruit setting which could make the plant balance between energy produced and its use for plant growth and fruit setting as well as fruit development (Verberne, 2006; Brakeboer, 2007).

Other information needed by the sweet pepper growers is the availibility of sweet pepper varieties or cultivars which are suitable under the plastic house growing condition in the tropic. This information is important so that the sweet pepper growers could have many options in their sweet pepper cultivation.

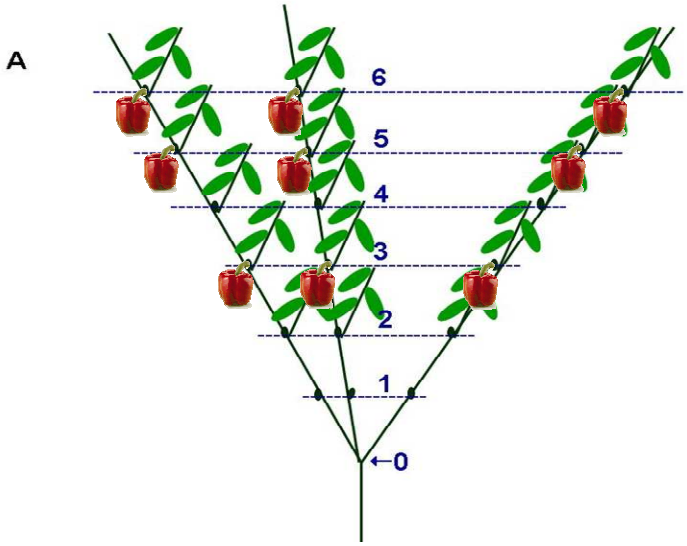
The objective of the experiments is to determine the effect of plant balancing system on the growth and yield of two sweet pepper varieties harvested green and colour .

2 MATERIALS AND METHODS

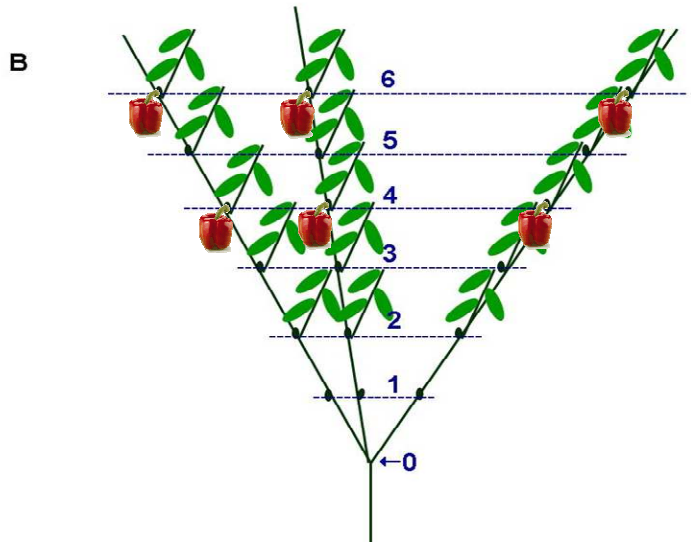
Two experiments in order to determine the effect of plant balancing on the growth and yield of two sweet pepper varieties harvested green and color were conducted i.e. one at the Indonesian Vegetable Research Institute (IVEGRI), Lembang (1250 m asl.), West Java and another one at a farmer farm in Pasirlangu, Cisarua sub-district, Bandung Barat district, West Java from May 2008 until January 2009. The treatments of the experiments were as follow:

1. Plant balancing system A: One fruit per stem on node 3 and 5; after that one fruit at each node
2. Plant balancing system B: One fruit per stem on node 4 and 6; after that one fruit at each node
3. Plant balancing system C: One fruit per stem on node 1; after that one fruit at each node

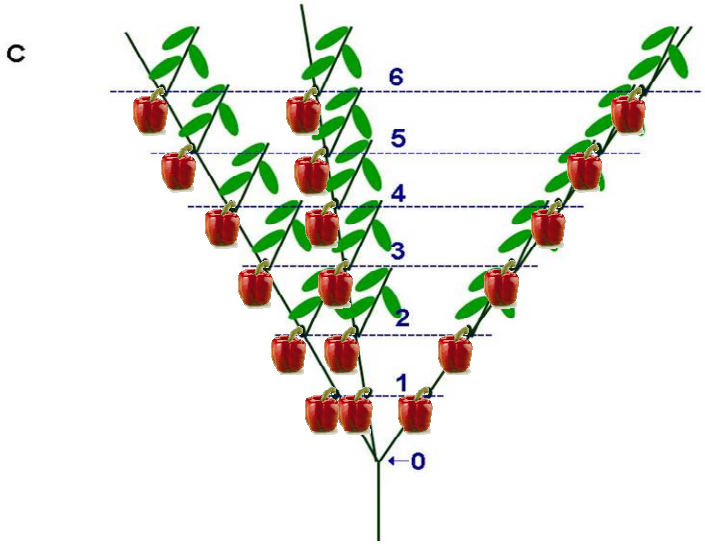
The technique of side shoot pruning and fruit selection in each treatment of plant balancing is presented in Fig. 1.



Plant balancing system A: One fruit per stem on node 3 and 5; after that one fruit at each node



Plant balancing system B: One fruit per stem on node 4 and 6; after that one fruit at each node



Plant balancing system C: One fruit per stem on node 1; after that one fruit at each node

Fig. 1. Three treatments of plant balancing systems applied in the experiments

In both experiments, two sweet pepper varieties were involved i.e.

1. Sunny (harvested yellow)
2. Spider (harvested red)
3. Spider (harvested green)

The treatment factors i.e. plant balancing system and varieties harvested green and colour were arranged in a Randomized Complete Block Design with three replications. The layout of each experiment area attached in Attachment 1 and Attachment 2.

The plants for both locations were sown on May 1, 2008 and planted in Experiment 1 (at IVEGRI) on June 5, 2008 and in Experiment 2 (at Pasirlangu) on June 6, 2008. In both experiments, green fruit harvest and color fruit harvest were determined using Sunny variety to be harvest as yellow fruit and Spider variety to be harvest as red fruit and green fruit. The latest harvest in Experiment 1 was on March 12, 2009 and in Experiment 2 was on November 26, 2008.

Fig. 2. The seedlings after transplanted to small polybags, Lembang 2008

2.1 Experiment 1

The experiment in IVEGRI was conducted in the wood-metal plastic house. This type of plastic house has been indicated as the better plastic house compared to the conventional bamboo plastic house, the common plastic house used by most sweet pepper farmers in Indonesia. The higher light intensity in the wood-metal plastic house has resulted in a better growing condition for sweet pepper plants and both fruit weight and fruit number per plant of crops grown in the wood-metal plastic house were significantly higher than those of crops grown in the bamboo plastic house (Gunadi *et al.* 2005; 2006). The wood-metal plastic house has a floor surface of 12.8 x 24.0 m.

In this experiment, the plants grown using three stems per plant system and the plant population used in the experiment was 8.4 stems per m^2. At the three stems per plant system, three similar stems were kept at the selection of the three stems, meaning that either the weakest or the strongest one was pruned in order to keep three equal stems. The growing media used in this experiment was carbonized rice husk. Carbonized rice husk is a growing media for sweet pepper cultivation commonly used by the farmers in West Java. Polybag with diameter of 40 cm was used as a container in the experiment. Using the three stems per plant system and plant population of 8.4 stems per m^2, the plant distance used was 120 cm between rows and 30 cm between plants or polybags. The sweet pepper plants in this experiment were grown using the cultivation technique recommended in the

Indonesian Vegetable Research Institute (IVEGRI) (Alberta, 2004; Morgan and Lennard, 2000; Gunadi *et al.* 2006).

Fig. 2. Transplanting the seedlings from the small polybags to big polybags, Lembang 2008

Fig. 3. The sweet pepper plants at one month after transplanting to the big polybags in the greenhouse, Lembang 2008

Fig. 4. The sweet pepper plants at four months after transplanting in the greenhouse, Lembang 2008

In Experiment 1, fertigation was applied using the drip irrigation system and controlled by the Rainbird equipment. The nutrition used was AB Mix produced by Buana Tani, Lembang, West Java. The contents of nutrients in this mix are based on the Naaldwijk A0.0.0. recommendation for sweet pepper cultivation (Sonneveld, 1988). From sowing till transplanting to the small polybag, EC 0.5 was applied, and from transplanting to the small polybag until transplanting to the big polybag, EC 1.0 was applied. One week after transplanting to the big polybag, EC 1.5 was applied and after that EC 2.0 was applied. After fruit set, EC 2.2 was applied.

For the fertigation two stock solutions of A and B were made by dissolving one pack A in 90 litre water and by dissolving pack B in another 90 litre water. In case a nutrition solution with EC 2.0 was desired, five litre of stock solution A and five litre of stock solution B was taken and dissolved in 990 litre of water. Consequently 1000 l of nutrition solution with EC 2.0 was prepared. For a lower or higher desired EC level respectively slightly more or less then 5 litres per stock solution A and B was taken. The solution was adjusted with clear water or extra stock solution when after measuring the EC with an EC meter. After the desired EC level was reached, the nutrition solution was also adjusted to pH 5.8 by adding HNO_3.

The frequency of fertigation was ten times a day i.e. at 7.30, 9.00, 10.30, 11.30, 12.30, 13.30, 14.30, 15.30, 17.00 and 24.00 hrs. The amount of water and nutrition applied depended on the drain measured. At the vegetative period, the desired drain level was 5 – 10%, whereas at the generative period, the desired drain level was 20 – 30%.

2.2 Experiment 2:

The experiment at the farmer's field was conducted in the traditional bamboo plastic house. The bamboo plastic house has a floor surface of 17.0 x 19.0 m. Similar to Experiment 1, in this experiment, the plants grown using three stems per plant system. At the three stems per plant system, three similar stems were kept at the selection of the three stems, meaning that either the weakest or the strongest one was pruned in order to keep three equal stems. The growing media used in this experiment was carbonized rice husk. Carbonized rice husk is a growing media for sweet pepper cultivation commonly used by the farmers in West Java. Polybag with diameter of 35 cm was used as a container in the experiment. Double row system was used in the experiment and the planting distance was 75 cm x (60 cm x 25 cm), which mean that 75 cm between beds of the double row, 60 cm between rows in the double row and 25 cm between plants or polybags (Fig. 5).

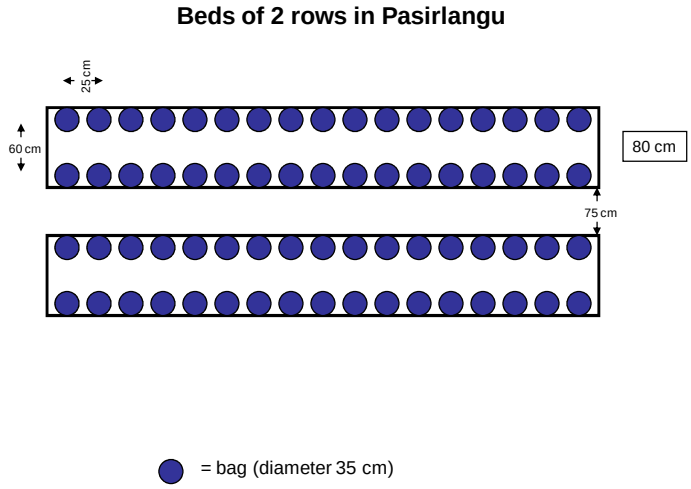


Fig. 5. Double row system used in Experiment 2 as practiced by most farmers in the area, Pasirlangu 2008

Fig. 6. Transplanting the seedlings from the small polybags to big polybags in Experiment 2, Pasirlangu 2008

Different with the fertigation system in Experiment 1, the fertigation in Experiment 2 was done manually using a plastic hose to one by one in each polybag. The frequency of fertigation was done depended the climatic condition. In the rainy season, the frequency of fertigation was only 1-2 times a day, but in the dry season, the frequency of fertigation could be 2-3 times a day. Similar to the Experiment 1, the nutrition used was AB Mix produced by Buana Tani, Lembang, West Java.

From planting, the EC was maintained at 2.0. In order to make the nutrition solution with EC 2.0, two stock solutions of A and B were made by dissolving one pack A in 90 litre water and by dissolving pack B in another 90 litre water. In case a nutrition solution with EC 2.0 was desired, five litre of stock solution A and five litre of stock solution B was taken and dissolved in 990 litre of water. Consequently 1000 l of nutrition solution with EC 2.0 was prepared.

Fig. 7. Fertigation was manually done using a plastic hose to each plant in the polybag, Pasirlangu 2008

Fig. 8. The sweet pepper plants at two months after transplanting in Experiment 2, Pasirlangu 2008

In each experiment plant height was measured just before transplanting to the big polybag or slab. Plant height was also measured after the seedlings were transplanted to the big polybag or slab at 4, 6, 8, 10, 12, 14, and 16 weeks after planting. Plant height was measured from the media surface to the tip of the leaves of the

tallest stem when pulled erect. Plant height was based on data from two representative plants in each plot. The number of node in each treatment was also counted at the same time as plant height measurement.

Twice a week, the plants were observed on mature fruits and fruits were harvested depending on the treatments. For fruits harvested red or red colour, the fruits were harvested at fully red and yellow coloured. For fruit harvested green, the fruits were harvested when the fruits were still green but firm enough. Fruits were graded according farmers practice. All fruits were individually graded on weight.

3 RESULTS

3.1 Experiment 1 (IVEGRI)

3.1.1 Crop growth

There was no significant interaction between plant balancing and variety (fruit colour harvested) on the growth parameter i.e. plant height observed during the growing season, therefore only the main factor effects are presented. The effect of plant balancing on plant height of sweet pepper during the growing period is presented in Table 1. At the initial growing period until 8 weeks after planting (WAP), plant balancing treatment did not affect the plant height of sweet pepper. In this experiment, the mean plant height of sweet pepper at 2, 4, 6 and 8 WAP were 13.9, 28.2, 44.2 and 62.5 cm, respectively. However at the further growing period, the plant height of sweet pepper were significantly differed between the plant balancing system. At 10 to 14 WAP, the sweet pepper plants with system A and B were always higher than those with system C.

Table 1. Effect of plant balancing on plant height during the growing period, Lembang 2008

Plant balancing	Plant height (cm) at						
	2 WAP	4 WAP	6 WAP	8 WAP	10 WAP	12 WAP	14 WAP
System A	13.9	28.9	43.8	63.1	83.9	98.6	115.0
System B	14.0	28.2	44.2	61.8	86.5	101.5	115.1
System C	13.8	28.1	44.7	62.5	77.1	87.8	99.1
Mean	13.9	28.4	44.2	62.5	82.5	95.9	109.7
Significance	ns	ns	ns	ns	**	***	***
CV (%)	5.9	5.8	4.1	5.1	6.2	4.3	3.9

Note: WAP = Week After Planting; CV = Coefficient of Variation; ns = not significant; ** = significant at 1%; *** = significant at 0.5%

The effect of plant balancing system was differed in each variety (fruit colour harvested). In variety Sunny (harvested yellow), the effect of plant balancing was initially indicated on August 13 (10 WAP) and on a further effect on November 20 (24 WAP), in which the sweet pepper plants with plant balancing system C had always lowest plant height compared to those of plants with plant balancing system A and B (Figure 9).

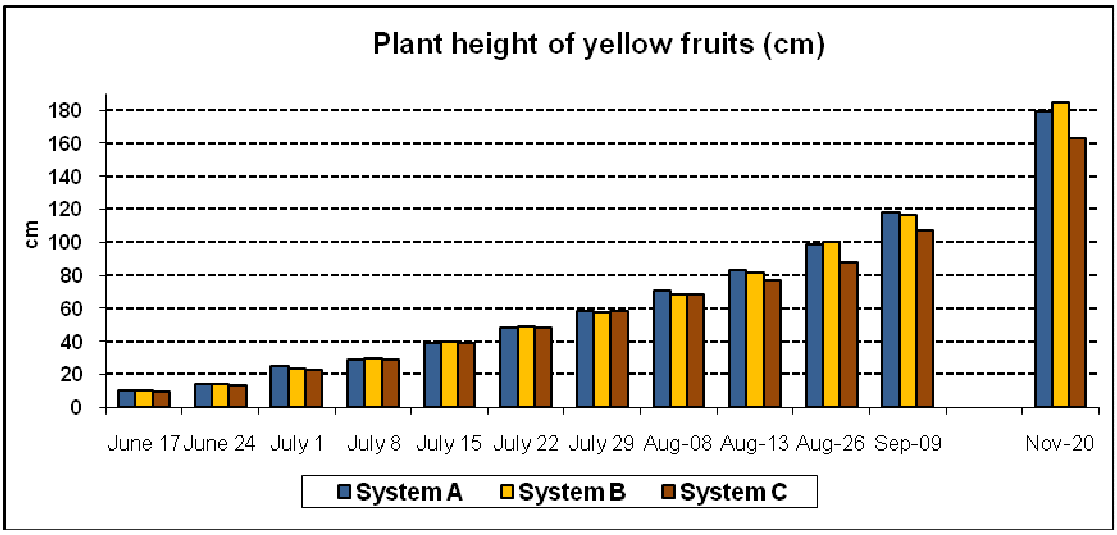


Fig. 9. Effect of plant balancing system on the plant height of variety Sunny (harvested yellow) during the growing period, Lembang 2008

Similar effect of plant balancing system was also indicated on variety Spider, which was harvested red. The effect of plant balancing system was initially indicated on August 8 (9 WAP) and the effect was further indicated until November 20 (24 WAP) (Figure 10). As also indicated in the variety Sunny (harvested yellow), in the variety Spider (harvested red), the plants with plant balancing system C had always lowest plant height compared to those of plants with plant balancing system A and B.

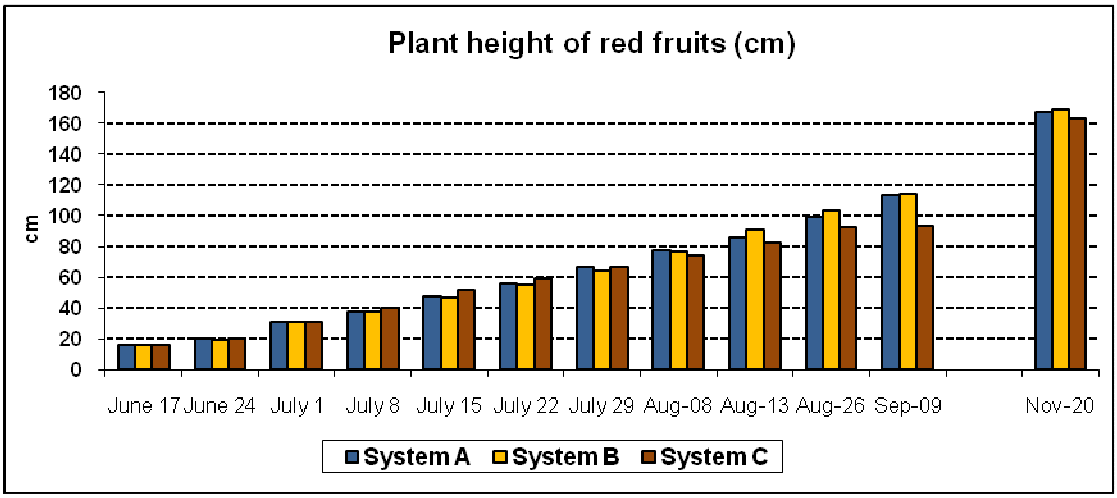


Fig. 10. Effect of plant balancing system on the plant height of variety Spider (harvested red) during the growing period, Lembang 2008

In the variety Spider (harvested green), the effect of plant balancing was also indicated since August 8 (9 WAP) and the effect was further indicated until November 20 (24 WAP) (Figure 11). As also indicated in the variety Sunny (harvested yellow) and variety Spider (harvested red), in the variety Spider (harvested green), the plants with plant balancing system C had always lowest plant height compared to those of plants with plant balancing system A and B.

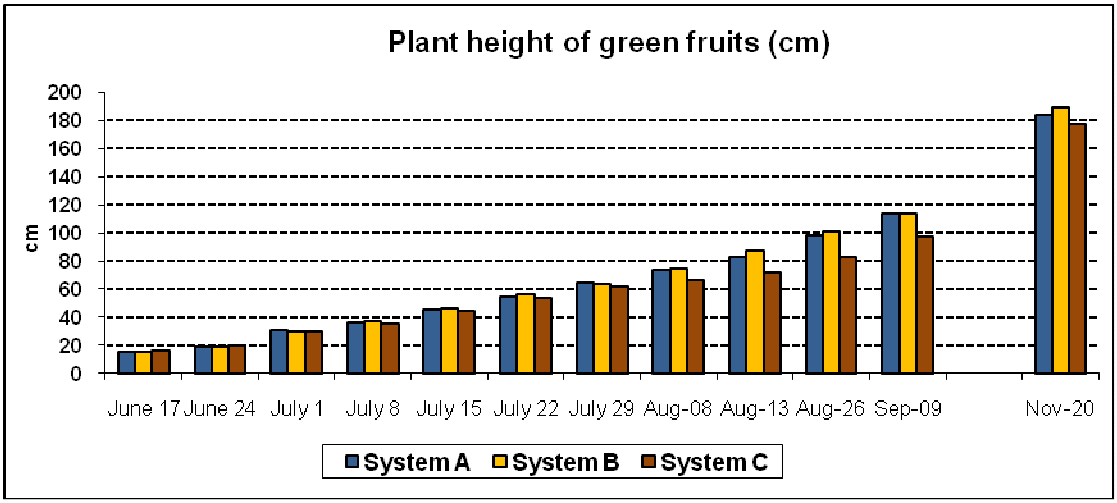


Fig. 11. Effect of plant balancing system on the plant height of variety Spider (harvested green) during the growing period, Lembang 2008

Data of plant height of the three sweet pepper varieties during the growing season is presented in Table 2. At the initial growth until 12 WAP, variety Spider (harvested red) had significantly higher plants than those of variety Sunny (harvested yellow) and variety Spider (harvested green). However, at a further growing period i.e. 14 WAP, the variety Sunny (harvested yellow) had significantly higher plants than those of variety Spider either harvested red or harvested green.

Table 2 . Plant height of the three varieties (fruit colour harvested) during the growing period, Lembang 2008

Variety (colour harvested)	Plant height (cm) at						
	2 WAP	4 WAP	6 WAP	8 WAP	10 WAP	12 WAP	14 WAP
Sunny (yellow)	10.2	23.8	39.0	58.1	80.4	95.6	113.7
Spider (red)	15.9	30.9	48.6	66.2	86.5	98.3	107.0
Spider (green)	15.6	30.4	45.1	63.1	80.7	94.0	108.5
Mean	13.9	28.4	44.2	62.5	82.5	95.9	109.7
Significance	***	***	***	***	**	***	***
CV (%)	5.9	5.8	4.1	5.1	6.2	4.3	3.9

Note: WAP = Week After Planting; CV = Coefficient of Variation; ns = not significant; ** = significant at 1%; *** = significant at 0.5%

3.1.2 Yields

The effect of plant balancing on the yields of sweet pepper in each class category is presented in Table 3. In this experiment, the plants with plant balancing system B gave the highest total yield compared to those of plants with plant balancing system A or system C (Figure 12), however the difference was not significant. The mean total

yields of sweet pepper plants with plant balancing system A, B and were 18.98, 19.05 and 18.60 kg per m^2, respectively.

Table 3. Effect of plant balancing system on the yields sweet pepper ($kg.m^{-2}$) in each class category, Lembang 2008

Plant balancing	Yields ($kg.m^{-2}$)			
	Total	> 200 g	100-200 g	< 100 g
System A	18.98	9.45	8.34	0.61
System B	19.05	9.00	8.88	0.62
System C	18.60	9.32	8.19	0.64
Mean	18.88	9.25	8.47	0.63
Significance	ns	ns	ns	ns
CV (%)	7.1	12.1	8.3	102.3

Note: CV = Coefficient of Variation; ns = not significant

The yield of fruits > 200 g of plants with plant balancing system A was higher than those of plants with plant balancing system B and C (Table 3 and Figure 12), however the diffrences were not significant. The mean yield of fruits > 200 g with plant balancing system A, B and C were 8.34, 8.88 and 8.19 kg per m^2, respectively. Similar to the effect of plant balancing system on total yields and yield of fruits > 200 g, the plant balancing system did not affect the yields of fruits 100-200 g and < 100g.

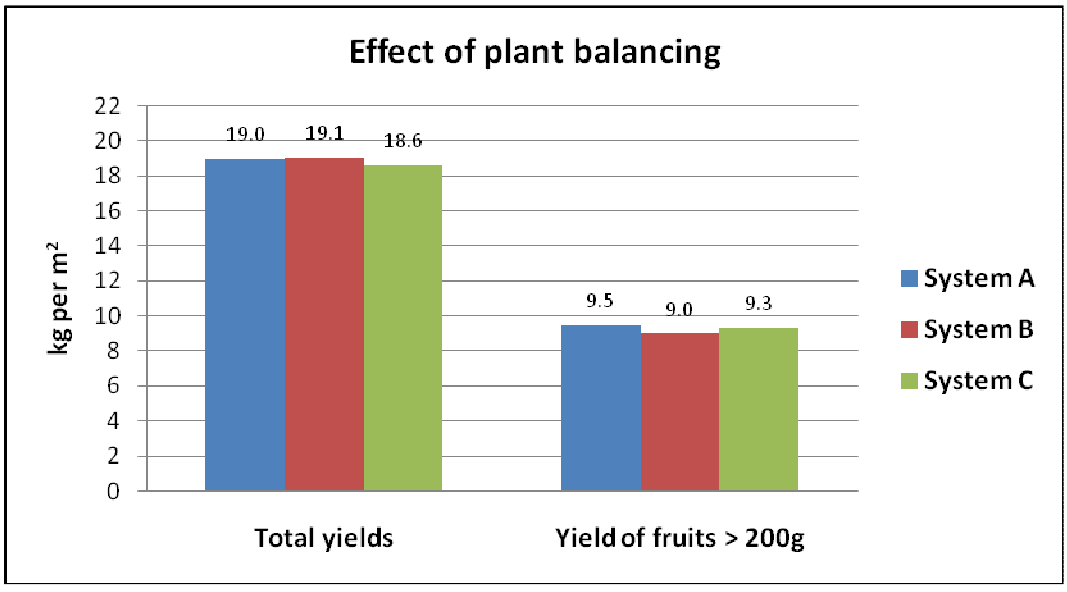


Fig. 12. Effect of plant balancing system on the total yields and yield of fruits > 200g, Lembang 2008

In order to determine the effect of plant balancing system on the yields of sweet pepper, the yield development of fruit > 200 g was illustrated at each harvest is presented in Figure 13. At the beginning of harvest

(September 18), the plants with plant balancing system C gave higher yield of fruits > 200 g compared to those of plants with plant balancing system A and B. However, starting at the middle of harvest (December 1), the plants with plant balancing system A gave higher yield of fruits > 200 g compared to those of plants with plant balancing system B and C. This trend was indicated until final harvest in March 9. The higher yield of fruits > 200 g in plants with plant balancing A at the middle harvest until the final harvest, however, was not significant compared to those in plants with plant balancing system B and C as indicated in Table 3.

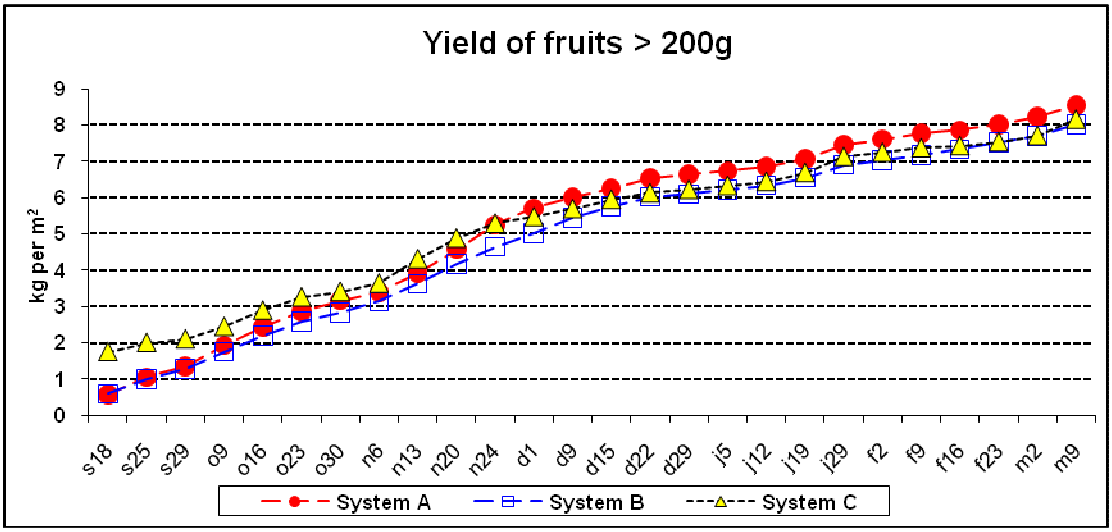


Fig. *13. Yield development of fruit > 200g as affected by plant balancing system, Lembang 2008*

The effect of plant balancing system on the number of fruits harvested in each class category is presented in Table 4. At the final harvest, the total number of fruits of plant with plant balancing system B was higher than those of plants with either plant balancing system A or system C (Figure 14), however the differences were not significant. The mean total number of fruits of plants with plant balancing system A, B, and C were 108.7, 113.0, and 107.6, respectively.

Table 4. Effect of plant balancing system on the number of fruits (#. m^{-2}) in each class category, Lembang 2008

Plant balancing	No. of fruits (#.m^{-2})			
	Total	> 200 g	100-200 g	< 100 g
System A	108.7	41.0	59.9	7.8
System B	113.0	39.2	64.2	9.6
System C	107.6	40.7	59.4	7.6
Mean	109.8	40.3	61.1	8.3
Significance	ns	ns	ns	ns
CV (%)	7.1	12.1	8.3	102.3

Note: CV = Coefficient of Variation; ns = not significant

In terms of number of fruits > 200 g, the highest fruit number was indicated in plants with plant balancing system B (Figure 14), however the differences were not significant. The mean number of fruits > 200 g of plants with plant balancing system A, B, and C were 41.0, 39.2, and 40.7, respectively.

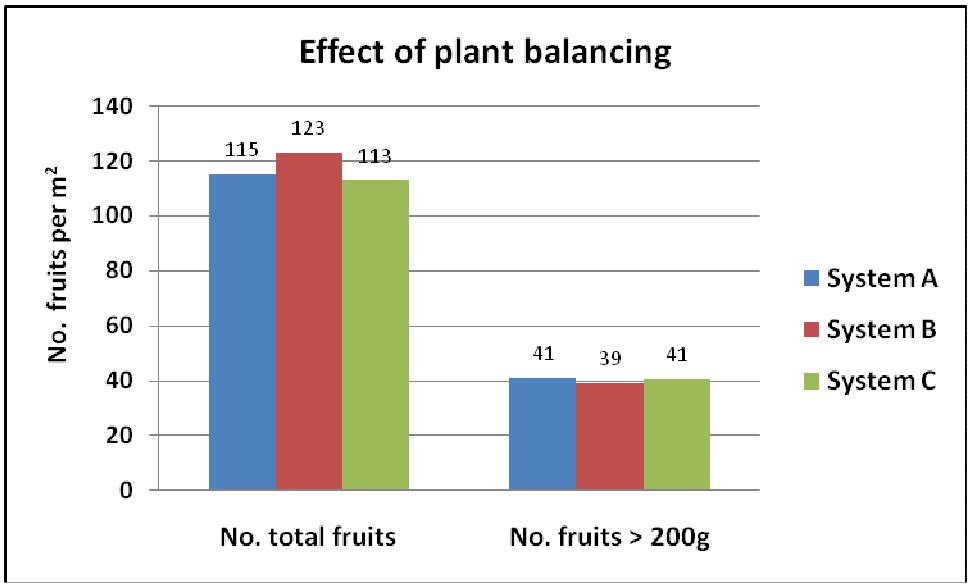


Fig. 14. Effect of plant balancing system on the total fruit number and number of fruits > 200g, Lembang 2008

The total yields and yield of fruits > 200 g of each variety harvested green and colour is presented in Figure 15.

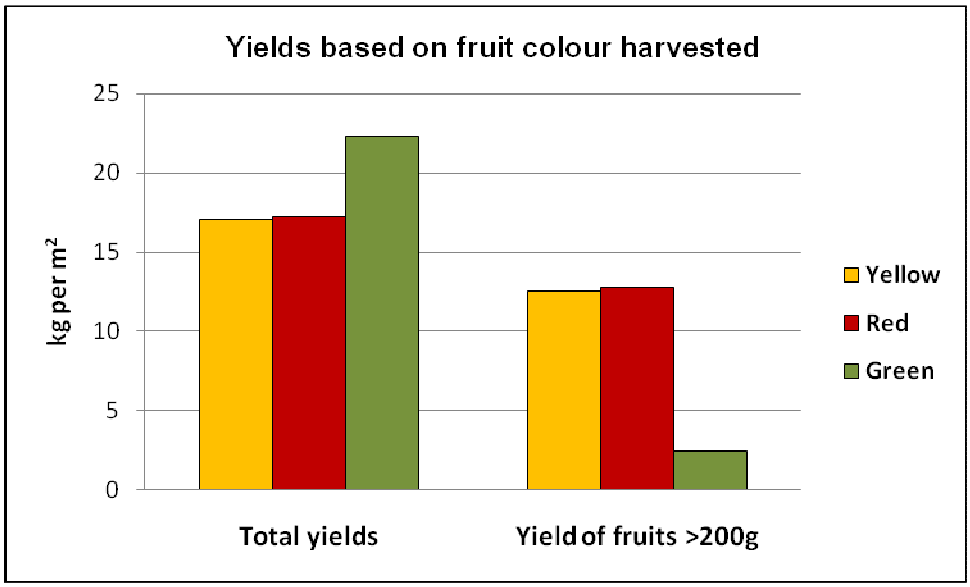


Fig. 15. Effect of plant balancing system and colour of fruit harvested on the total yields and yield of fruits > 200g, Lembang 2008

The highest total yields of sweet pepper was obtained by the plants of variety Spider (harvested green) which was 22.35 kg per m^2 and followed by the plants of variety Spider (harvested red) and variety Sunny (harvested yellow). The total yields of variety Spider (harvested green) were in average 30% higher than those of variety Spider (harvested red) and variety Sunny (harvested yellow). The mean total yields of variety Spider (harvested red) and variety Sunny (harvested yellow) were 17.23 and 17.06 kg per m^2, respectively. In contrast, the yield of fruits > 200 g of variety Spider (harvested green) was only 19% of those of variety Spider (harvested red) and variety Sunny (harvested yellow) (Figure 15). The mean yields of fruits > 200 g of variety Spider (harvested green), Spider (harvested red) and variety Sunny (harvested yellow) were 2.42, 12.74 and 12.56 kg per m^2, respectively.

Similar trends of the effect of plant balancing system and colour of fruit harvested on the total yields and yield of fruits > 200 g, were also indicated on the total number of fruits and number of fruits > 200 g (Figure 16). The highest total number of fruits was obtained by the plants of variety Spider (harvested green) which was 171.1 fruits per m^2 and followed by the plants of variety Spider (harvested red) and variety Sunny (harvested yellow).

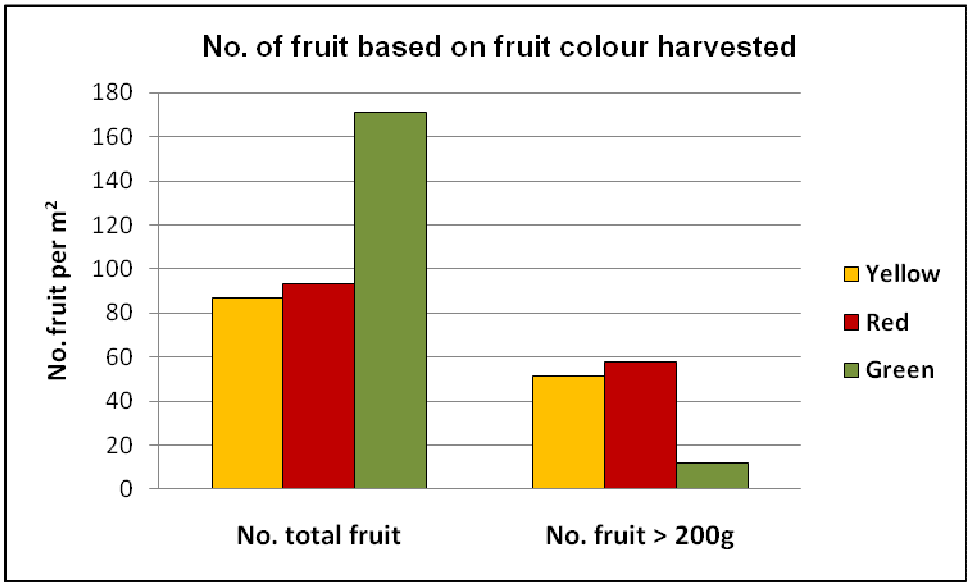


Fig. 16. Effect of plant balancing system and colour of fruit harvested on the total fruit number and number of fruits > 200g, Lembang 2008

The total number of fruits of variety Spider (harvested green) were in average 83% and 97% higher than those of variety Spider (harvested red) and variety Sunny (harvested yellow), respectively. The mean total number of fruits of variety Spider (harvested red) and variety Sunny (harvested yellow) were 93.3 and 86.6 fruits per m^2, respectively. In contrast, the number of fruits > 200 g of variety Spider (harvested green) was only 3.9% of those of variety Spider (harvested red) and 3.4 % of those of variety Sunny (harvested yellow), respectively (Figure 16). The mean number of fruits > 200 g of variety Spider (harvested green), Spider (harvested red) and variety Sunny (harvested yellow) were 11.7, 57.6 and 51.6 fruits per m^2, respectively.

The effect of plant balancing system on the mean weight of variety Sunny (harvested yellow) is presented in Figure 17. In general, the mean fruit weight of variety Sunny (harvested yellow) was more stable with plant balancing system C compared to those with plant balancing system A and B. However, at the end of harvesting time, the plant balancing system did not affect the mean fruit weight of variety Sunny (harvested yellow). The mean fruit weight of variety Sunny (harvested yellow) in this experiment was 219 gram.

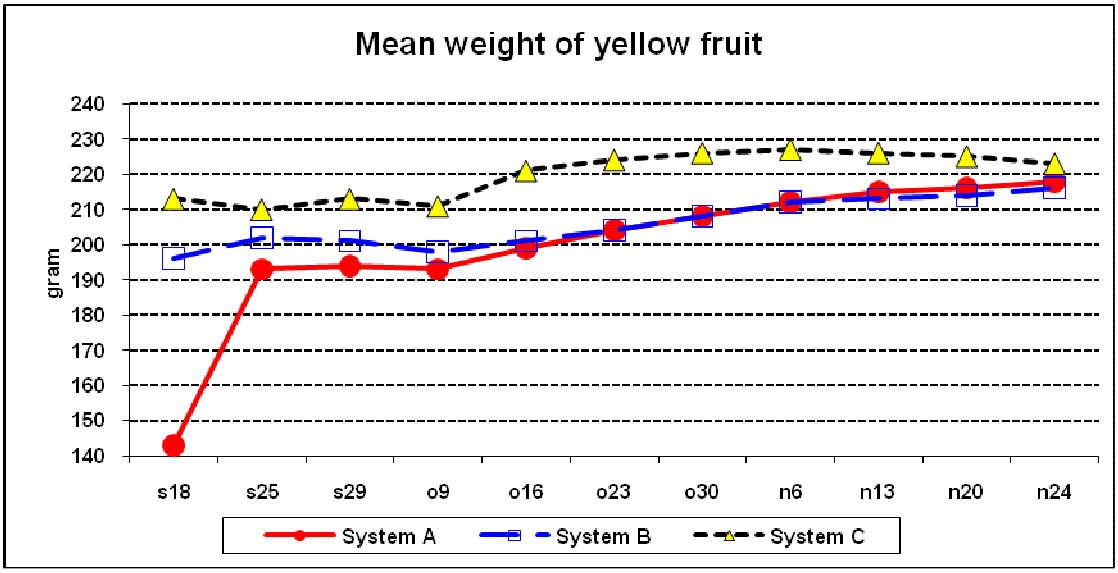


Fig. 17. Effect of plant balancing system on the mean fruit weight of variety Sunny (harvested yellow), Lembang 2008

In the variety Spider (harvested red), the effect of plant balancing system significatly affected the mean fruit weight (Figure 18). From October 16, the mean fruit weight of plants with plant balancing system A was significatly higher than those of plants with plant balancing system B and C. The mean fruit weight of plants with plant balancing system A was also the most stable from the beginning of harvest until the final harvest compared to those of plants with plant balancing system B and C. This was presumably related to the side shoot pruning and fruit selection system applied in the treatment (Figure 1). The mean fruit weight of variety Spider (harvested red) in plants with plant balancing system A, B and C in this experiment were 215, 202 and 197 gram, respectively.

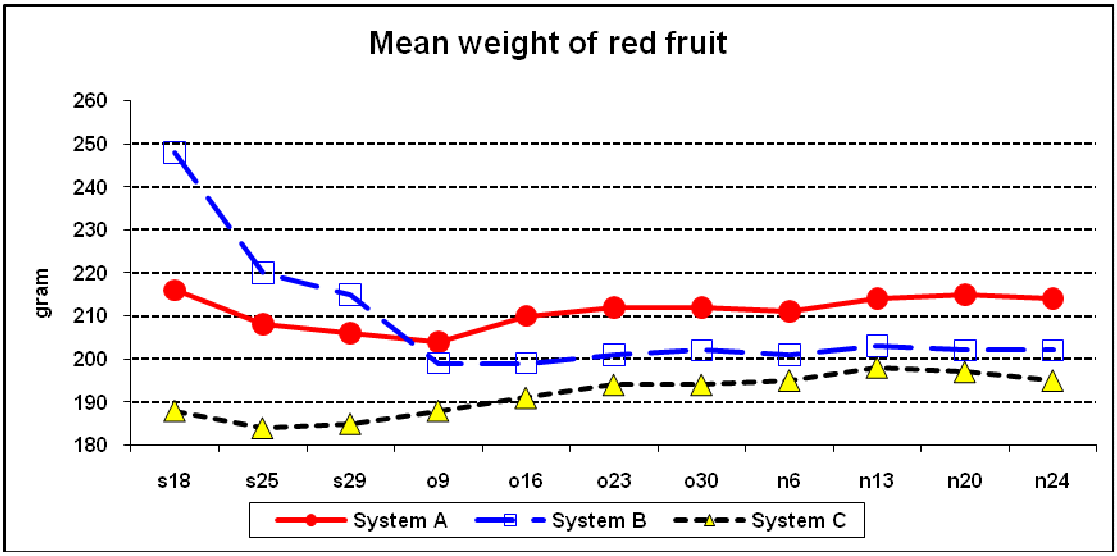


Fig. 18. Effect of plant balancing system on the mean fruit weight of variety Spider (harvested red), Lembang 2008

Similar to the variety Sunny (harvested yellow), the plant balancing system did not affect the mean fruit weight of variety Spider (harvested green) (Figure 19). Although the mean fruit weight of variety Spider (harvested green) was higher in the plants with plant balancing system C, the differences were not significant until the final harvest. The mean fruit weight of variety Spider (harvested green) in this experiment was 144 gram.

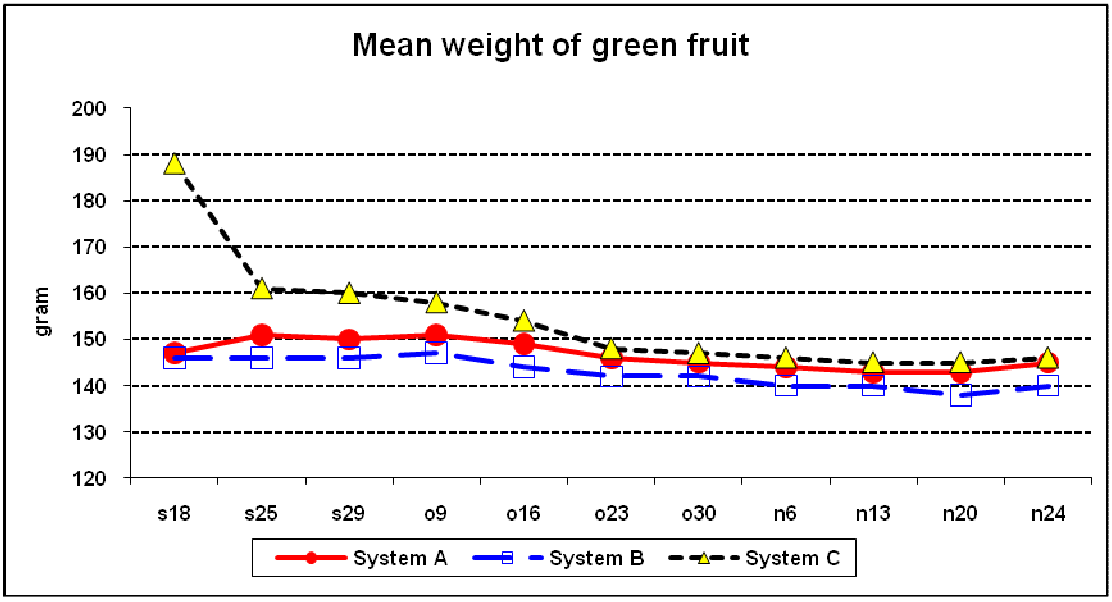


Fig. 19. Effect of plant balancing system on the mean fruit weight of variety Spider (harvested green), Lembang 2008

3.2 Experiment 2 (Pasirlangu)

3.2.1 Crop growth

The plant balancing system affected the plant height of each variety (fruit colour harvested). In general similar pattern was found in all varieties tried in this experiment. In variety Sunny (harvested yellow), the effect of plant balancing was initially indicated on July 16 (6 WAP) and the effect was more obvious at the later stage of growing period, in which the sweet pepper plants with plant balancing system C had always lowest plant height compared to those of plants with plant balancing system A and B (Figure 20).

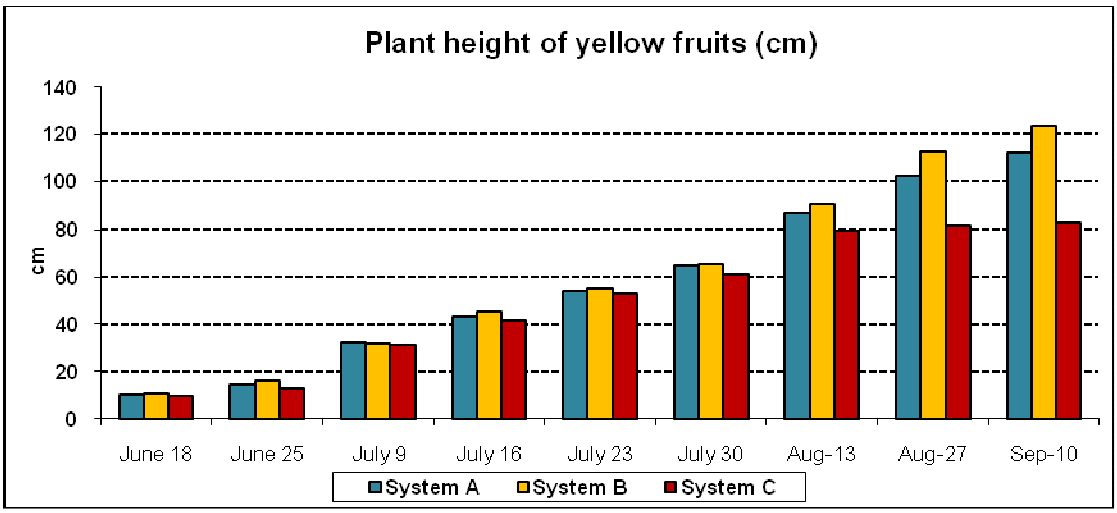


Fig. 20. Effect of plant balancing system on the plant height of variety Sunny (harvested yellow) during the growing period, Pasirlangu 2008

Similar pattern as in the variety Sunny (harvested yellow) was also found in the variety Spider (harvested red). In this variety, the effect of plant balancing was initially indicated on August 13 (10 WAP) and the effect was more obvious at the later stage of growing period, in which the sweet pepper plants with plant balancing system C had always lowest plant height compared to those of plants with plant balancing system A and B (Figure 21).

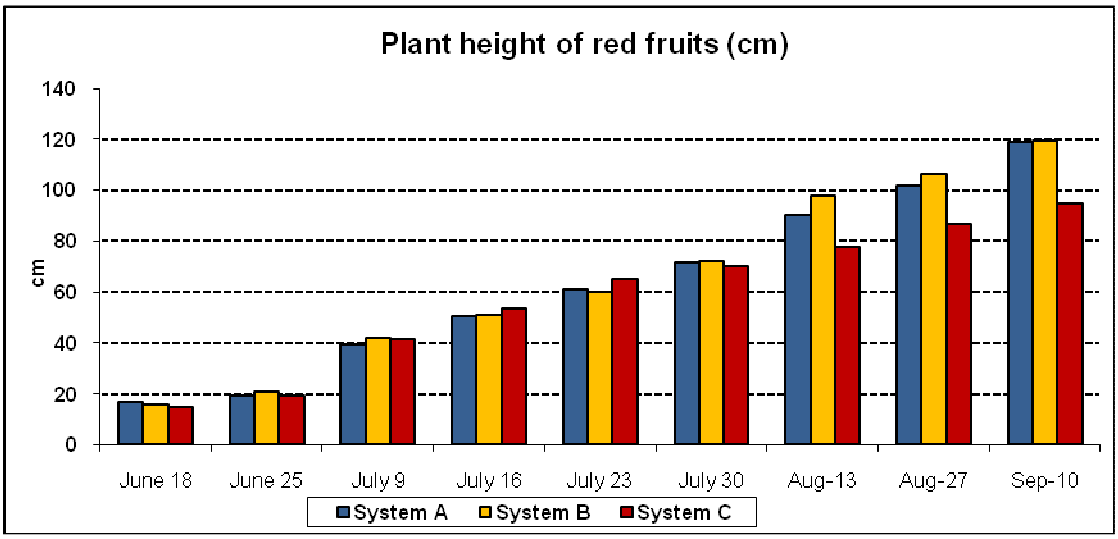


Fig. 21. Effect of plant balancing system on the plant height of variety Spider (harvested red) during the growing period, Pasirlangu 2008

In the variety Spider (harvested green), similar pattern as in the two varieties mentioned earlier was also found in the variety Spider (harvested green). The effect of plant balancing was initially indicated on August 13 (10 WAP) and the effect was more obvious at the later stage of growing period, in which the sweet pepper plants with plant balancing system C had always lowest plant height compared to those of plants with plant balancing system A and B (Figure 22).

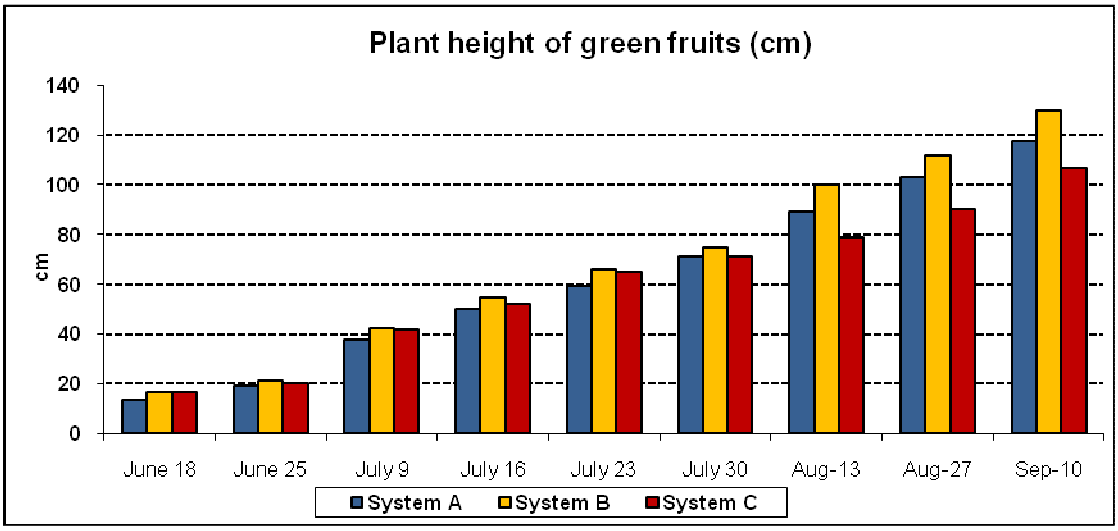


Fig. 22. Effect of plant balancing system on the plant height of variety Spider (harvested green) during the growing period, Pasirlangu 2008

3.2.2 Yields

The effect of plant balancing system on the yields of sweet pepper is presented in Table 5. In terms of total yields, plants with plant balancing system A had highest total yields but the differences was only significant with plants with plant balancing system C (Figure 23).

Table 5. Effect of plant balancing system on the yields sweet pepper (kg.m^{-2}) in each class category, Pasirlangu 2008

Plant balancing	Yields (kg.m^{-2})			
	Total	> 200 g	100-200 g	< 100 g
System A	5.21	2.38	2.54	0.28
System B	5.01	1.96	2.65	0.40
System C	4.65	2.08	2.20	0.34
Mean	4.96	2.14	8.47	0.34
LSD 5%	0.34	0.38	0.23	0.13

Note: LSD = Least Significant Difference

The yield of fruits > 200 g of plants with plant balancing system A was also the highest however the diffrences were only significant with plants with plant balancing system B (Figure 23).

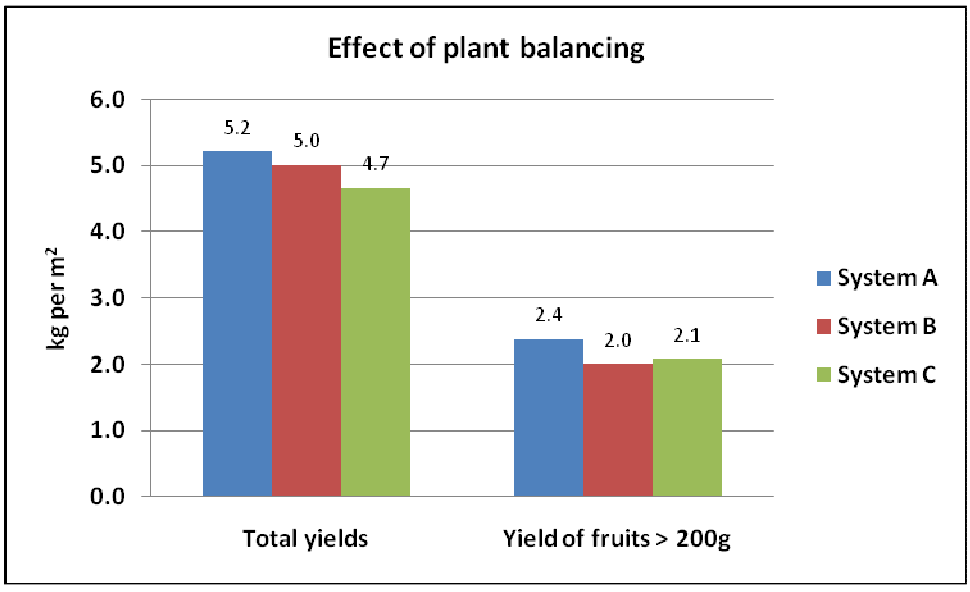


Fig. 23. Effect of plant balancing system on the total yields and yield of fruits > 200g, Pasirlangu 2008

In order to determine the effect of plant balancing system on the yields of sweet pepper in this experiment, the yield development of fruit > 200 g was illustrated at each harvest is presented in Figure 24. At the

beginning of harvest (August 18), the plants with plant balancing system C gave higher yield of fruits > 200 g compared to those of plants with plant balancing system A and B. However, starting at the middle of harvest (October 8), the plants with plant balancing system A gave always higher yield of fruits > 200 g compared to those of plants with plant balancing system B and C. This trend was indicated until final harvest in November 26. The higher yield of fruits > 200 g in plants with plant balancing system A compared to plants with plant balancing system B and C at the middle of harvest until the final harvest was also indicated as in Table 5.

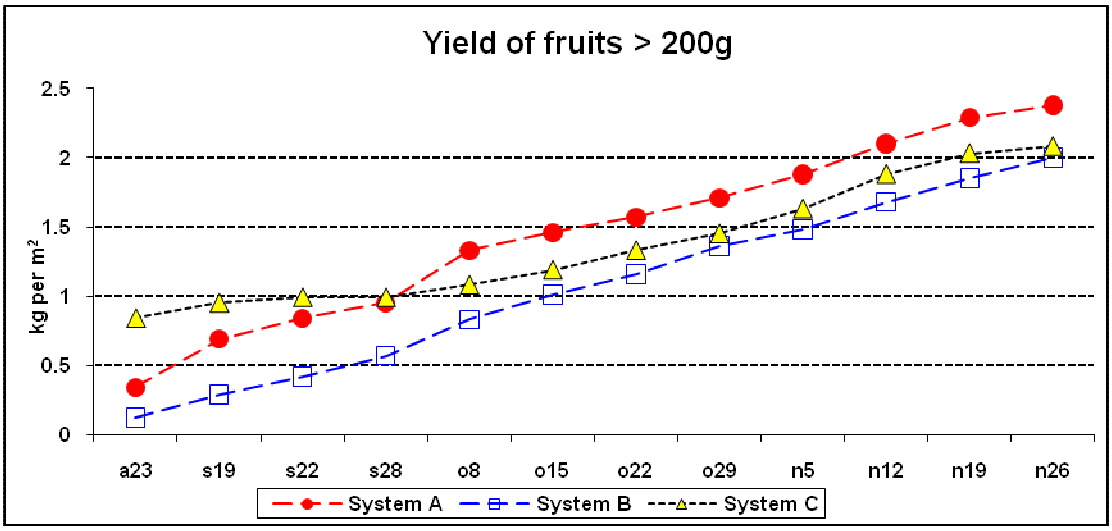


Fig. 24. Yield development of fruit > 200g as affected by plant balancing system, Pasirlangu 2008

The effect of plant balancing system on the number of fruits harvested in each class category is presented in Table 6. At the final harvest, the total number of fruits of plant with plant balancing system B was higher than those of plants with either plant balancing system A or system C (Figure 25), however the differences were not significant. The mean total number of fruits of plants with plant balancing system A, B, and C were 33.2, 34.0, and 32.3, respectively.

Table 6. Effect of plant balancing system on the number of fruits (#.m^{-2}) in each class category, Pasirlangu 2008

Plant balancing	No. of fruits (#.m^{-2})			
	Total	> 200 g	100-200 g	< 100 g
System A	33.2	10.8	16.9	3.8
System B	34.1	9.0	18.2	5.1
System C	32.3	9.4	14.9	4.9
Mean	33.2	9.7	16.7	4.6
LSD 5%	3.4	1.9	1.4	1.3

Note: LSD = Least Significant Difference

In terms of number of fruits > 200 g, the highest fruit number was indicated in plants with plant balancing system A (Figure 25), however the differences were not significant. The mean number of fruits > 200 g of plants with plant balancing system A, B, and C were 10.8, 9.0, and 9.4, respectively.

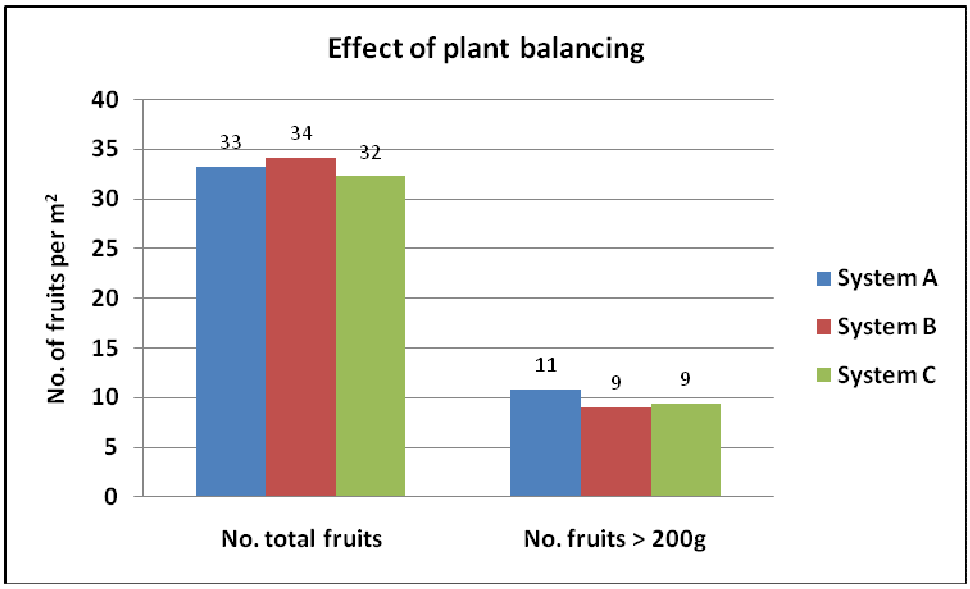


Fig. 25. Effect of plant balancing system on the total fruit number and number of fruits > 200g, Pasirlangu 2008

The total yields and yield of fruits > 200 g of each variety harvested green and colour is presented in Figure 26. As in experiment 1, the highest total yields of sweet pepper was obtained by the plants of variety Spider (harvested green) which was 6.17 kg per m^2 and followed by the plants of variety Spider (harvested red) and variety Sunny (harvested yellow). The total yields of variety Spider (harvested green) were in average 39% higher than those of variety Spider (harvested red) and 44% higher than those of variety Sunny (harvested yellow). The mean total yields of variety Spider (harvested red) and variety Sunny (harvested yellow) were 4.43 and 4.27 kg per m^2, respectively. In contrast, the yield of fruits > 200 g of variety Spider (harvested green) was only 41% of those of variety Spider (harvested red) and 53% of those of variety Sunny (harvested yellow) (Figure 26). The mean yields of fruits > 200 g of variety Spider (harvested green), Spider (harvested red) and variety Sunny (harvested yellow) were 1.33, 2.28 and 2.81 kg per m^2, respectively.

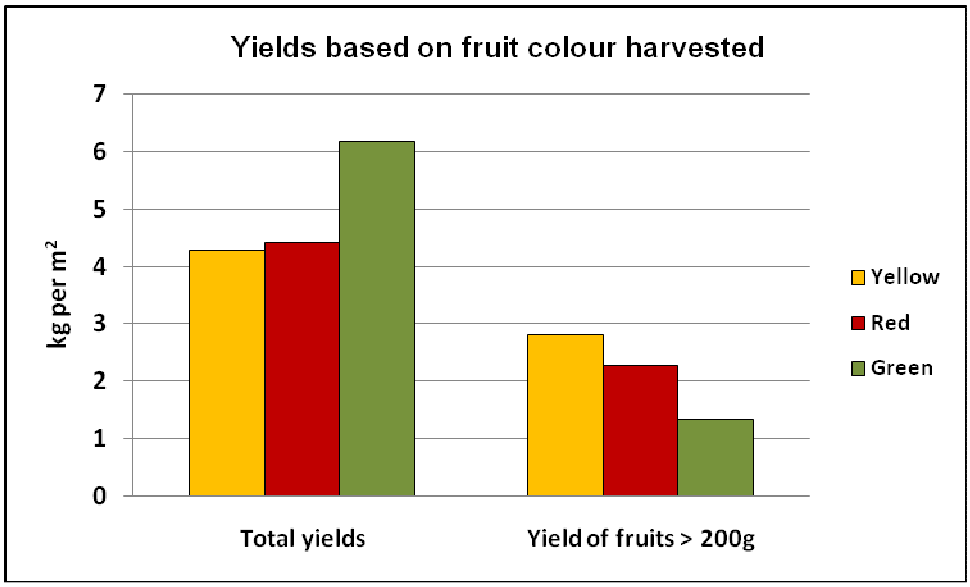


Fig. 26. Effect of plant balancing system and colour of fruit harvested on the total yields and yield of fruits > 200g, Pasirlangu 2008

Similar trends of the effect of plant balancing system and colour of fruit harvested on the total yields and yield of fruits > 200 g, were also indicated on the total number of fruits and number of fruits > 200 g (Figure 27). The highest total number of fruits was obtained by the plants of variety Spider (harvested green) which was 47.1 fruits per m^2 and followed by the plants of variety Spider (harvested red) and variety Sunny (harvested yellow).

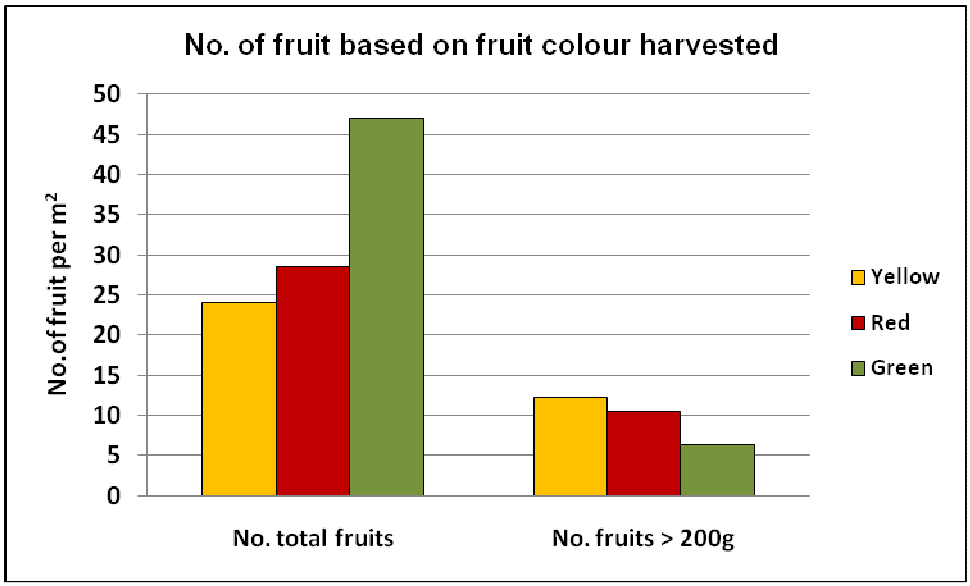


Fig. 27. Effect of plant balancing system and colour of fruit harvested on the total fruit number and number of fruits > 200g, Pasirlangu 2008

The total number of fruits of variety Spider (harvested green) were in average 65% and 96% higher than those of variety Spider (harvested red) and variety Sunny (harvested yellow), respectively. The mean total number of fruits of variety Spider (harvested red) and variety Sunny (harvested yellow) were 28.4 and 24.0 fruits per m^2,

respectively. In contrast, the number of fruits > 200 g of variety Spider (harvested green) was only 39% of those of variety Spider (harvested red) and 48 % of those of variety Sunny (harvested yellow), respectively (Figure 27). The mean number of fruits > 200 g of variety Spider (harvested green), Spider (harvested red) and variety Sunny (harvested yellow) were 6.4, 10.5 and 12.3 fruits per m^2, respectively.

The effect of plant balancing system on the mean weight of variety Sunny (harvested yellow) is presented in Figure 28. In general, the mean fruit weight of variety Sunny (harvested yellow) was more stable with plant balancing system C compared to those with plant balancing system A and B as also indicated in Experiment 1. However, at the end of harvesting time, the plant balancing system did not affect the mean fruit weight of variety Sunny (harvested yellow). The mean fruit weight of variety Sunny (harvested yellow) at the final harvest in this experiment was 185 gram.

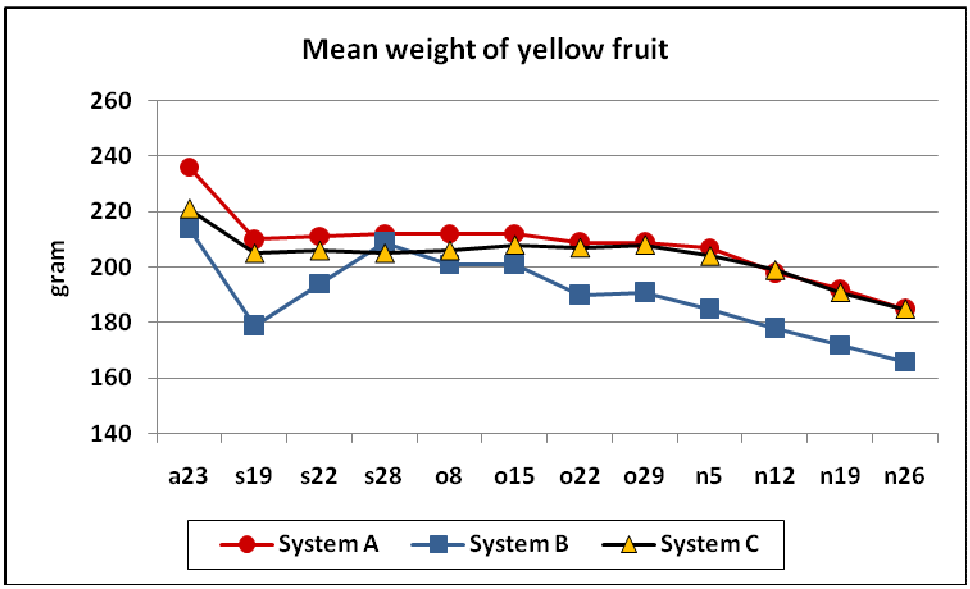


Fig. 28. Effect of plant balancing system on the mean fruit weight of variety Sunny (harvested yellow), Pasirlangu 2008

In the variety Spider (harvested red), the effect of plant balancing system significatly affected the mean fruit weight (Figure 29). The mean fruit weight of plants with plant balancing system A was significatly higher than those of plants with plant balancing system B and C. The mean fruit weight of variety Spider (harvested red) in plants with plant balancing system A, B and C at the final harvest in this experiment were 172, 163 and 139 gram, respectively.

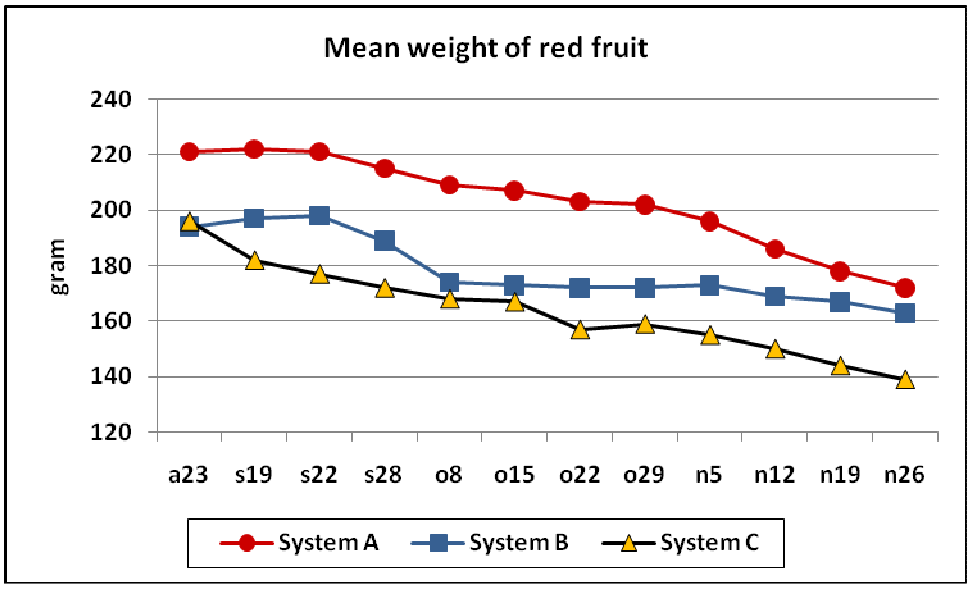


Fig. 29. Effect of plant balancing system on the mean fruit weight of variety Spider (harvested red), Pasirlangu 2008

As in the variety Spider (harvested red), the plant balancing system significantly affected the mean fruit weight of variety Spider (harvested green) especially at the beginning of harvest (Figure 30). The mean fruit weight of variety Spider (harvested green) in plants with plant balancing system A, B and C at the final harvest in this experiment were 135, 131 and 129 gram, respectively.

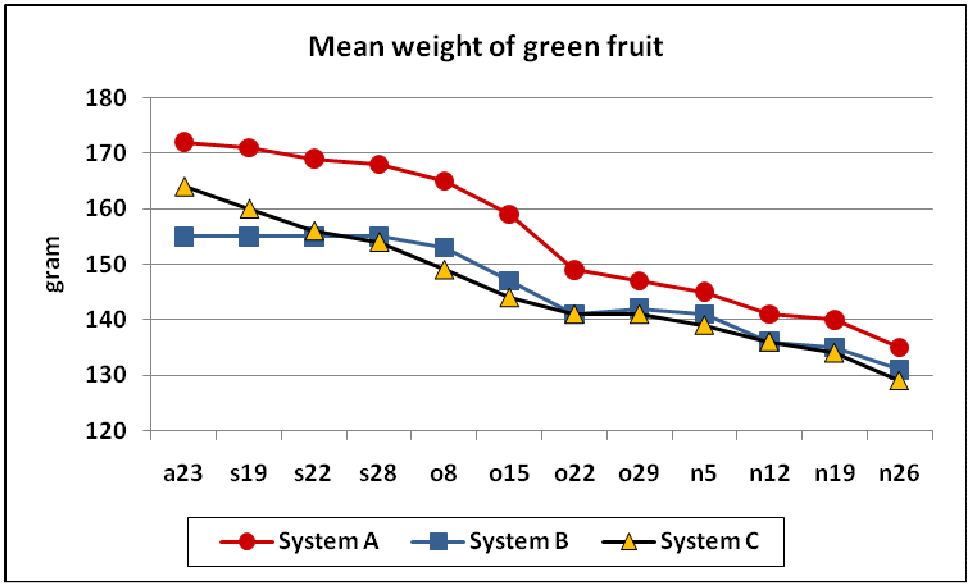


Fig. 30. Effect of plant balancing system on the mean fruit weight of variety Spider (harvested green), Pasirlangu 2008

4 DISCUSSION

The main objective of this experiment was to determine the effect of plant balancing system on the growth and yield of two sweet pepper varieties harvested green and colour. The plant balancing system did not significantly affect the total yields and yield of fruits > 200 g, although in the growth parameter which was indicated by plant height observed that the plant balancing system affected significantly the plant height especially at the late stage of the growing period and the plants with plant balancing system C had always lowest plants than those of plants with plant balancing system A and B in Experiment 1 (Figures 9, 10 and 11) and in Experiment 2 (Figures 20, 21 and 22). The result was differed with the result of the earlier experiment with the side shoot pruning and fruit selection. In the earlier experiment, although the total yields of sweet pepper were not significantly differed between plants with the introduction pruning system and the conventional pruning system, the plants with the introduction pruning system gave higher yields of grade A compared to plants with the conventional pruning system. The introduction pruning system gave also more uniform fruits compared to the conventional pruning system (Gunadi *et al*., 2005). In addition, the absent of the significant effect of plant balancing system in this experiment was presumably related to the source:sink ratio. In the sweet pepper plant, fruit setting is positvely correlated with the source strength and is negatively correlated with the sink strength and therefore positively correlated with source:sink ratio (Heuvelink *et al*., 2002). The variation in weekly production in the sweet pepper plants was also related to the plant fruit load manipulation (Abdel-Mawgoud *et al*., 2008).

In these experiments, variety Spider (harvested green) had the highest total yields than variety Spider (harvested red) and variety Sunny (harvested yellow) either in Experiment 1 (Figure 15) and in Experiment 2 (Figure 26). However, the yield of fruits > 200 g of variety Spider (harvested green) was lower than those of variety Spider (harvested red) and variety Sunny (harvested yellow). The higher total yields of variety Spider (harvested green) than those of variety Spider (harvested red) and variety Sunny (harvested yellow) was presumably related to the source:sink ratio. The energy produced in plants of variety Spider (harvested green) was not fully used in the earlier formed fruits due to the early harvest of the green fruits and therefore the energy produced could be used to form other fruits. Thus, the total yields of variety Spider (harvested green) were higher than those of variety Spider (harvested red) and variety Sunny (harvested yellow). Harvesting green fruit in the sweet pepper cultivation is one of the methods in order to stimulate the growth and fruit setting which could make the plant balance between energy produced and its use for plant growth and fruit setting as well as fruit development (Verberne, 2006; Brakeboer, 2007). Harvesting green fruits allows the sweet pepper plants to stimulate the new and more fruit setting compared to harvesting colour fruits in which the energy produced from the photosynthesis process will be used first for the development of fruits formed earlier and the setting of new fruits will be inhibited. Therefore the yields of plants with harvesting colour fruits were lower than those of plants with harvesting green fruits. The lower yield of fruits > 200 g of variety Spider (harvested green) than those of variety Spider (harvested red) and variety Sunny (harvested yellow) was due to the early harvest and therefore the fruits produced were still small.

Differences in total yields were observed between experiments and in general the total yields of Experiment 1 conducted at IVEGRI were higher than those of Experiment 2 conducted at a farmer's farm in Pasirlangu. The experiment in IVEGRI was conducted in a wood-metal plastic house while the experiment in Pasirlangu was conducted in a bamboo plastic house. In the earlier experiment (Gunadi et al., 2005; 2006) plastic house construction affected significantly the yield of sweet pepper. The crop grown in the wood-metal plastic house gave a higher yield and a higher number of fruits per plant compared to that grown in the bamboo plastic

house. The higher yield and number of fruit of crops grown in the wood-metal plastic house was presumably associated with a higher light intensity present in the wood-metal plastic house compared to that in the bamboo plastic house. On average, the light intensity in the wood-metal plastic house was 13-20% higher than that in the bamboo plastic house. The higher light intensity in the wood metal type plastic house resulted in better growing conditions for sweet pepper. This resulted in a better growing condition and therefore the crop grown in the wood-metal plastic house yielded significant higher number of fruit per square meter than the crop grown in the bamboo plastic house. One factor that is considered as the most important factor that affects flowering, fruit setting and growth and development of sweet pepper is the light intensity (Demers *et al*., 1998; Zornoza *et al*., 1988; Wien, 1997; Calpas, 2002; Morgan and Lennard, 2000). A low light intensity would often result in a lower yield of sweet pepper (Bakker, 1998; Kwon and Chun, 1999) and a high light interception in sweet pepper will increase the yields (Hand *et al*., 1993; Warren Wilson *et al*., 1992; Fierro *et al*., 1994; Demers *et al*., 1998).

5 CONCLUSIONS

1. The plant balancing system did not significantly affect the total yields and yield of fruits > 200 g, although in the growth parameter which was indicated by plant height observed that the plant balancing system affected significantly the plant height especially at the late stage of the growing period and the plants with plant balancing system C had always lowest plants than those of plants with plant balancing system A and B.
2. The total yields and total number of fruits of variety Spider (harvested green) were significantly higher than those of variety Spider (harvested red) and variety Sunny (harvested yellow), however the yield and number of fruits > 200 g of variety Spider (harvested green) were significantly lower than those of variety Spider (harvested red) and variety Sunny (harvested yellow).
3. Differences in total yields were observed between experiments and in general the total yields of Experiment 1 conducted in the wood-metal plastic house at IVEGRI were higher than those of Experiment 2 conducted in the bamboo plastic house at a farmer's farm in Pasirlangu.

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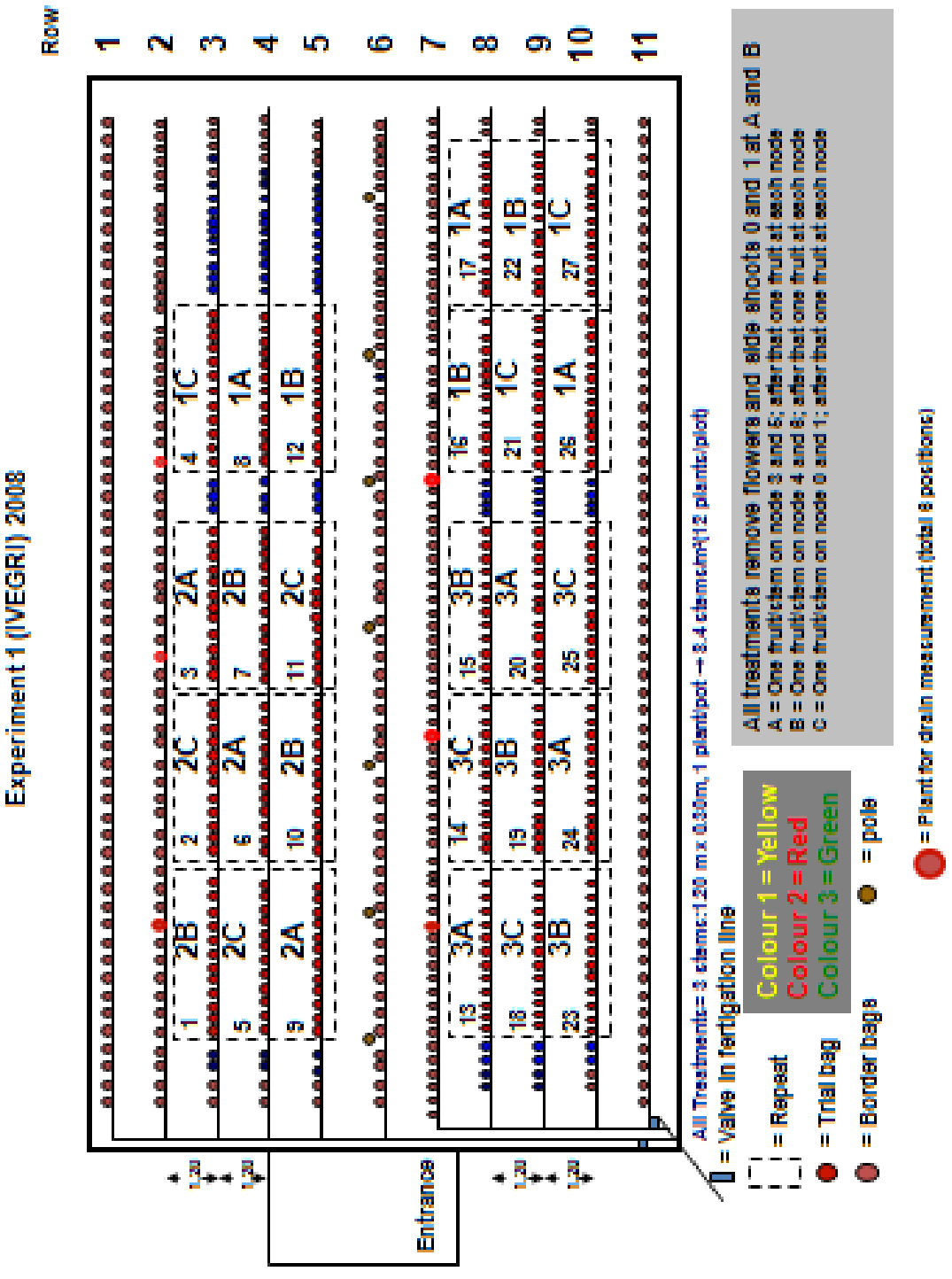
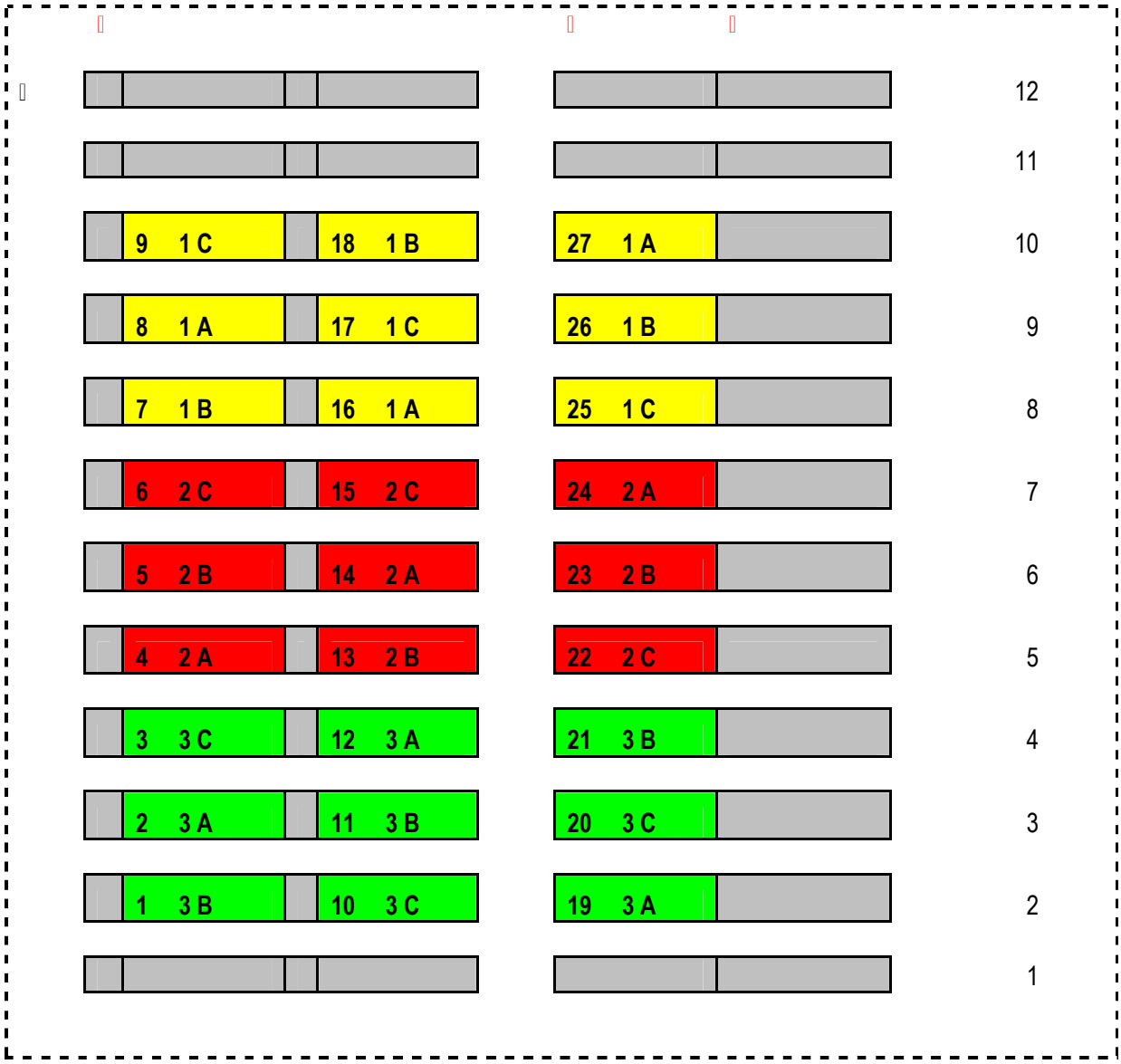
Appendix I. Layout of Experiment 1 in IVEGRI



Appendix II. Layout of Experiment 2 in Pasirlangu, West Java



1 = Sunny variety harvested yellow
2 = Spider variety harvested red
3 = Spider variety harvested green

Treatments of plant balancing in the experiment:
A = Plant balancing system A: One fruit/stem on node 3 and 5; after that one fruit at each node
B = Plant balancing system B: One fruit/stem on node 4 and 6; after that one fruit at each node
C = Plant balancing system C: One fruit/stem on node 1; after that one fruit at each node