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# Effect of plant spacing and harvesting frequency on the yield of Swiss chard cultivars (*Beta vulgaris* L.) in a closed hydroponic system

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**The objective of this study was to determine the combined effect of plant densities and leaf harvesting frequencies on yield of two hydroponically grown Swiss chard cultivars. Swiss chard plantlets were transplanted 28 days after seeding, utilizing a gravel-film technique hydroponic system. Thirty treatment combinations were used, namely two Swiss chard cultivars ('Ford Hook Giant' and 'Star 1801'), five plant densities (10, 16, 25, 40 and 50 plants/m$^2$), combined with three leaf harvesting frequencies (after every 7, 14 and 21 days). The first harvest with measurement of leaf area, fresh and dry mass, and number of leaves was done 30 days after transplanting. The results demonstrate that the Swiss chard cultivars responded differently to harvesting frequencies and plant densities. The highest yield was obtained with cultivar 'Ford Hook Giant', at a plant density of 40 plants/m$^2$, when plants were harvested on a biweekly basis. With cultivar Star 1801, harvesting frequency had no significant effect on yield. Plant density of 40 plants/m$^2$ combined with harvesting frequency of 14 days are therefore recommended to improve yield of 'Ford Hook Giant'.**

**Key words:** Leaf fresh mass, leaf area, leaf dry mass, plant density.

## INTRODUCTION

Swiss chard (*Beta vulgaris* L.), often incorrectly referred to as spinach, is a leafy vegetable that is popular in South Africa for its nutritional properties. Swiss chard is an annual cool weather crop with an optimum growth temperature of 16 to 24°C, and is well adapted to hot conditions and long days (Niederwieser, 2001). It has large, fleshy, dark green leaves and broad leaf stalks are usually white, but sometimes red or orange in ornamental forms (van Wyk, 2005). Harvesting is done by removing the outer matured leaves at specific intervals during the growth season. In Africa, the leaves and leaf stalks or a whole leaf blade are eaten as a vegetable side dish with a staple food after being shredded and cooked.

Swiss chard is a highly nutritious crop frequently grown in rotation with other crops (Smith et al., 2001). Apart from its high energy value of 20 kcal per 100 g cooked leaves, the leaves also contain relatively high levels of bioactive compounds, such as vitamin C and vitamin A (30 mg 100 g$^{-1}$ and 6116 I U, respectively), and also minerals, such as potassium (379 mg 100 g$^{-1}$), sodium (213 mg 100g$^{-1}$) and iron (1.80 mg 100g$^{-1}$) (USDA, 2010).

Improved yield and quality of leafy vegetables have been reported in a closed hydroponic system (Maboko and Du Plooy, 2009) due to more efficient use of water and nutrients. Although the majority of Swiss chard production in South Africa is still carried out in open field

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cultivation, soilless cultivation of vegetables has gained interest and popularity with farmers due to improved yield and quality (Maboko et al., 2011). Vegetables that are produced hydroponically are of high value, and can play an important role in income generation for small holder and commercial farmers (Du Plooy et al., 2012). According to Resh (1996), vegetable production in a soilless culture (hydroponics) is highly productive, conserves water and land, and is more environmentally friendly compared to field production. Recent trends in soilless cultivation focus on closed hydroponic systems to avoid nutrient losses and thereby protect the environment (Schwarz et al., 2009).

Plant spacing or density plays an important role to optimise yield (Žnidarčič et al., 2011; Maboko and Du Plooy, 2009; Badi et al., 2004). Too high or too low plant populations can result in lower yields and quality, with altered recommendations in the literature on plant spacing for Swiss chard production for open field and hydroponic production systems. Grubben and Denton (2004), reported that Swiss chard can be planted in an open field at a spacing of 30 × 30 cm. Whereas, Niederwieser (2001) recommended a plant spacing of 20 × 20 cm to 25 × 25 cm when planting Swiss chard in a closed hydroponic system using the gravel film technique. However, in spite of the high nutritional value of Swiss chard, information on present and newly introduced cultivars regarding the optimal spacing and leaf harvesting frequency in soilless production systems are not available. The objective of this study was to determine the effect of cultivar, plant density and leaf harvesting frequencies on yield of Swiss chard grown in a closed hydroponic system (gravel-film hydroponic systems).

## MATERIALS AND METHODS

A trial was conducted between the 1st August to the 23rd November 2011 in a 40% black and white shadenet structure at the Agricultural Research Council -Vegetable and Ornamental Plant Institute (ARC-VOPI), Roodeplaat, South Africa (25°59' S; 28°35' E and at an altitude of 1 200 m.a.s.l). Swiss chard seeds of open pollinated cultivars (Cultivar 'Star 1801', Starke Ayres seed Pty. Ltd., South Africa; cultivar 'Ford Hook Giant', Hygrotech Seed Pty. Ltd., South Africa) were sown in July 2011 in 200 cavity polystyrene trays filled with a commercial growth medium, Hygromix® (Hygrotech Seed Pty. Ltd., South Africa) and covered with a thin layer of vermiculite after sowing. Cultivar 'FordHookGiant' is a well-known cultivar in South Africa due to its vigorous growth and tolerance to bolting, while cultivar 'Star 1801' is a new introductory. Seedlings were transplanted 28 days after sowing into a gravel-film technique hydroponic system as described by Maboko and Du Plooy (2011). The gravel-film technique is based on the nutrient-film technique system, where the nutrient solution flows down gullies by gravitation. The nutrient solution is pumped to the top of the gullies where a thin layer of nutrient solution flows by gravitation into the reservoir at the bottom of the gullies, from where it is then pumped back to the top of the gullies (re-circulating system). In the system utilised for the experiment, four tubes at the top of the gullies released the nutrient solution at a rate of 700 ml/min per tube (2800 ml/min), with continuous re-circulation as described previously. The pH and electrical conductivity (EC) of the nutrient solution was measured using a pH/EC meter (HANNA Combo instrument), and maintained within a range of 5.8 to 6.1 and 2.0 to 2.4 mS/cm, respectively. The composition and chemical concentration of fertilizers used for Swiss chard were: Hygroponic (HygrotechSeed Pty. Ltd., South Africa), comprising of N (68 mg/kg), P (42 mg/kg), K (208 mg/kg), Mg (30 mg/kg), S (64 mg/kg), Fe (1.254 mg/kg), Cu (0.022 mg/kg), Zn (0.149 mg/kg), Mn (0.299 mg/kg), B (0.373 mg/kg) and Mo (0.037 mg/kg), and calcium nitrate [$Ca(NO_3)_2$], comprising of N (117 mg/kg) and Ca (166 mg/kg). An amount of 1000 g Hygroponic and 900 g $Ca(NO_3)_2$ were applied in 1000 L of water, and the nutrient solution was renewed with fresh nutrient solution on a weekly basis. Thirty treatment combinations were used, including three leaf harvesting frequencies (after every 7, 14 and 21 days) and two Swiss chard cultivars (FordHook Giant and Star 1801), combined with five plant densities (10, 16, 20, 25 and 40 plants/m$^2$ at a plant spacing of 40×25, 25×25, 25×20, 20×20 and 10×25 cm, respectively). A randomised complete block design with two replicates was used in this experiment. Each plot size was 2 m × 1 m. Data-loggers (Gemini Data Loggers, United Kingdom), placed in a Stevenson type screen (ACS-5050) at a height of 1.5 m, were used to record temperature (Table 1).

Harvesting was initiated 30 days after transplanting (DAT) by removing all the outer matured leaves and leaving four small inner leaves. After the initial harvest at 30 DAT, plants subjected to harvesting frequencies every 7, 14 and 21 days resulted in a total number of harvests of 12, 6 and 4 times, respectively for a period of 84 days. The total growing period of the Swiss chard was therefore, 114 days (30 days + 84 days). At each harvest date, leaf area, leaf fresh and dry mass were measured for six data plants per treatment and replicate. The leaf area (cm$^2$) was measured using a leaf area meter (LI-3100 area meter, USA). Leaves were dried in an oven at 70°C for 48 h for leaf dry mass determination.

Data was subjected to analysis of variance (ANOVA) using the statistical program *GenStat*® version 11.1 (Payne et al., 2008).Treatment means were separated using Fisher's protected T-test least significant difference (LSD) at the 5% level of significance (Snedecor and Cochran, 1980).

## RESULTS AND DISCUSSION

The accumulated data for all harvests per treatment is presented.

### Effect of plant density

Different yield parameters of Swiss chard were significantly affected by plant densities (Figures 1 to 3). There was a significant increase in leaf fresh mass, leaf number and leaf area with an increase in plant density, with the exception of plant densities of 16 or 20 plants/m$^2$,which performed similarly (Figures 1 to 3). The highest leaf fresh mass, leaf number and leaf area were obtained at a plant population of 40 plants/m$^2$.The results are in agreement with previous findings on another crop, namely leafy lettuce (Maboko and Du Plooy, 2009), where as leaf yield per unit area increased due to increased plant density, while leaf yield per plant decreased with increasing plant density. Although the lower plant density (10 plants/m$^2$) gave more leaves,

**Table 1**. Maximum, minimum and mean monthly ambient temperatures (°C) in the shade net structure during the experimental period.

| Month | Maximum | Average | Minimum |
|---|---|---|---|
| September | 33.9 | 18.2 | 2.7 |
| October | 40.0 | 20.8 | 5 |
| November | 38.0 | 22.4 | 6.3 |

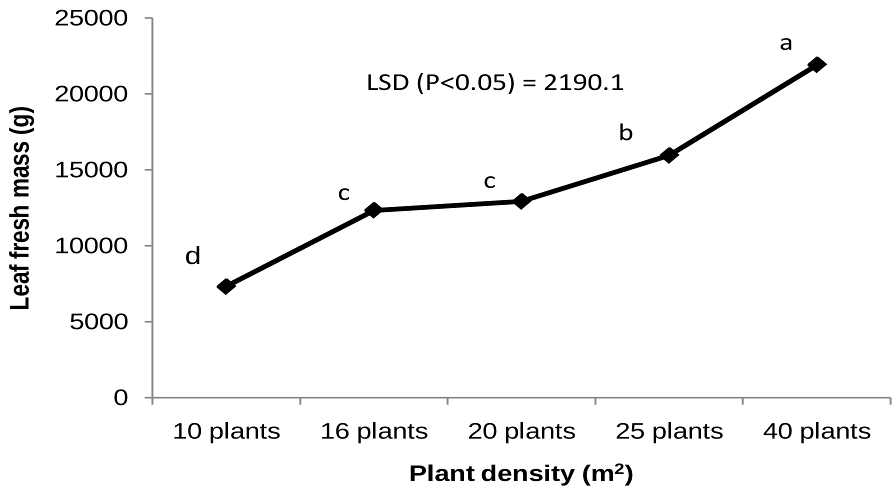


**Figure 1.** Effect of plant density on leaf fresh mass. Figures with different letters denote significant difference at the 5% level.

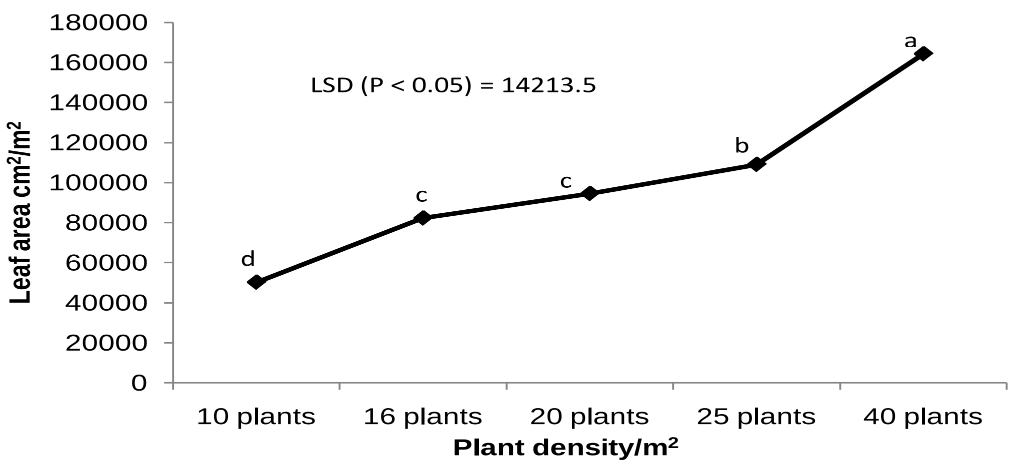


**Figure 2.** Effect of plant density on leaf area. Figures with different letters denote significant difference at the 5% level.

larger leaf area and higher leaf fresh mass per plant, as compared to high plant densities, it still resulted in lower yields per unit area. At closer spacing, Swiss chard leaves were forced to grow upright and faster due to the competition for sunlight. In contrast, the wider spaced plants resulted in leaves growing more horizontal with an open growing pattern.

**Interaction effects of plant spacing and harvesting frequency on leaf dry mass**

Results show that the high plant density of 40 plants/$m^2$ combined with a harvesting frequency of 14 days resulted in the highest leaf dry mass, followed by harvesting frequencies of 7 and 21 days at the same plant density

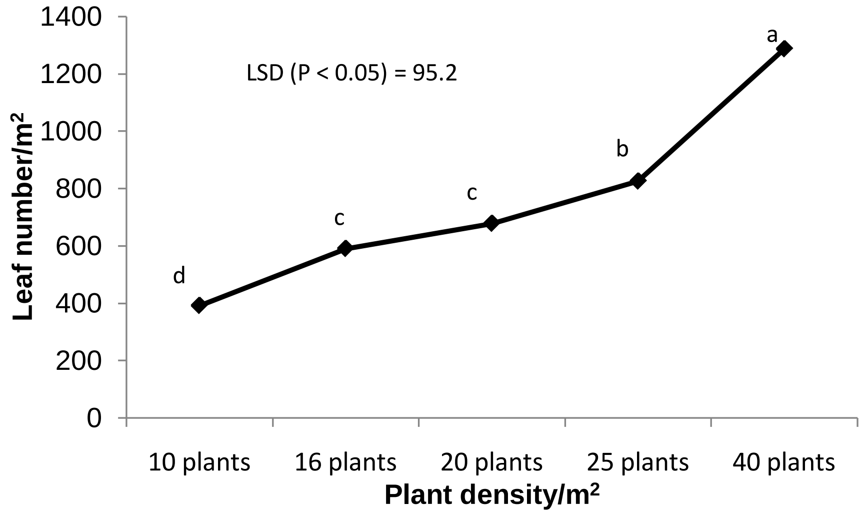


**Figure 3.** Effect of plant density on leaf number. Figures with different letters denote significant difference at the 5% level.

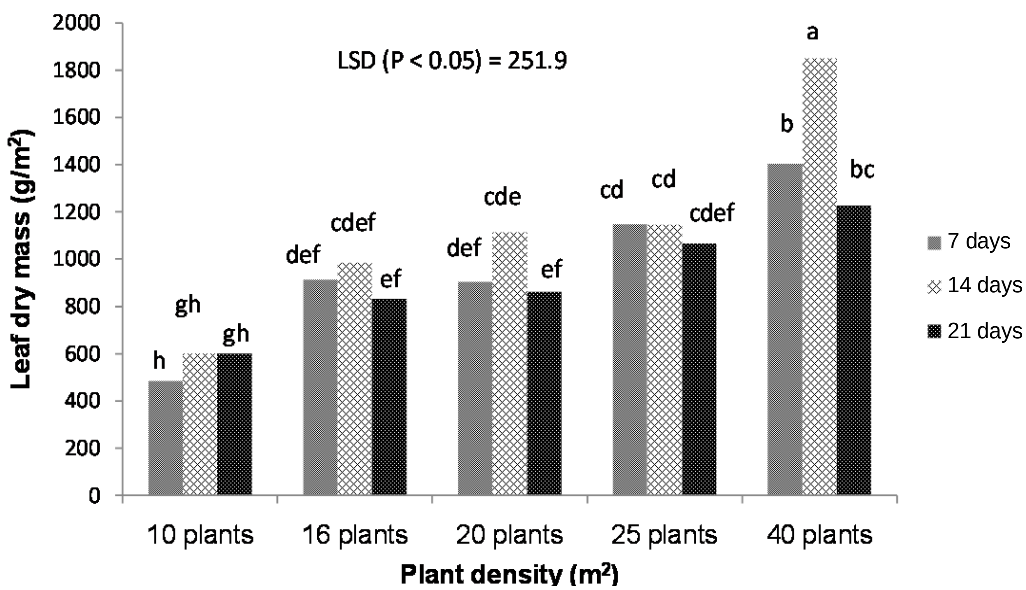


**Figure 4.** Interaction effects of plant spacing and harvesting frequency on leaf dry mass. Columns with different letters denote significant difference at the 5% level.

(Figure 4). There was a tendency of increased leaf dry mass with an increase in plant densities and harvesting frequencies of 7 and 14 days, while harvesting frequency of 21days reduced leaf dry mass (Figure 4). Increase in leaf dry mass at high density plantings is directly correlated with increases in leaf fresh mass, leaf number and leaf area, with an increase in plant densities.

**Interaction effect of cultivars and leaf harvesting frequencies**

'Ford Hook Giant' yielded higher leaf fresh and dry mass at a harvesting frequency of 14 days, compared to 7 and 21 days harvest intervals, which did not differ significantly (Figures 5 and 6). The cultivar 'Star 1801'showed no significant differences in leaf fresh and dry mass across all harvesting frequencies and was outperformed by 'Ford Hook Giant' on all yield parameters measured. Saidi et al. (2010) reported the highest yield of cowpea when harvested at 7 day intervals compared to 14 days which led to higher grain yield. Cultivar 'Ford Hook Giant' produced larger and high number of leaves when harvested at 7 and 14 days, compared to when harvested at 21 days, while cultivar 'Star 1801' performed similarly with all harvesting frequencies (Figures 7 and 8). The

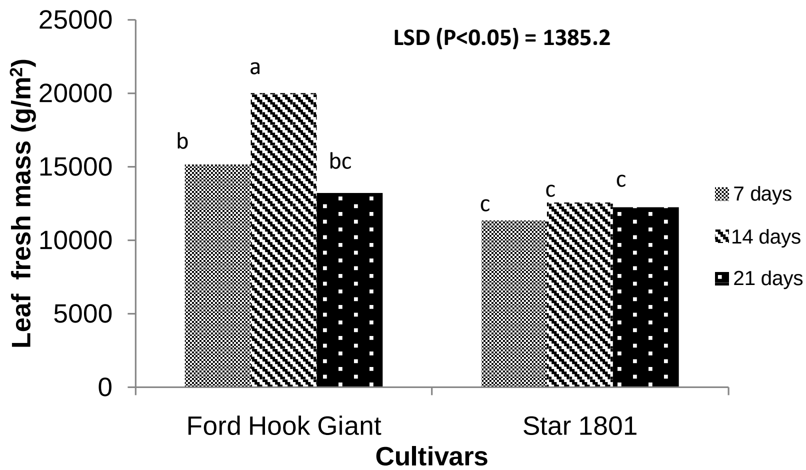


**Figure 5.** Interaction effect of harvesting frequencies and cultivars on leaf fresh mass. Columns with different letters denote significant difference at the 5% level.

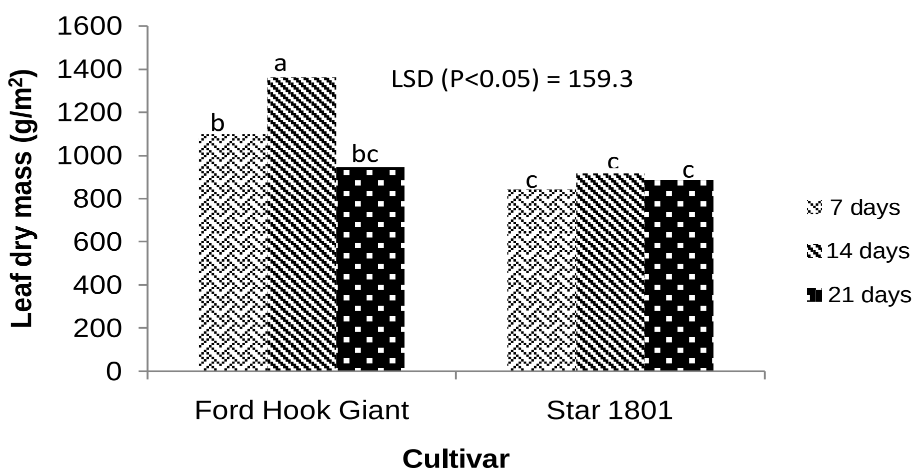


**Figure 6.** Interaction effect of harvesting frequencies and cultivars on leaf dry mass. Columns with different letters denote significant difference at the 5% level.

vigorous growth habit of cultivar ‘Ford Hook Giant’ compared to cultivar ‘Star 1801’ could be ascribed as the reason for the differences in performance of the two cultivars.

Generally, harvesting matured leaves of Swiss chard encourages regrowth of new leaves and increases yield. However, the results with two cultivars evaluated in a closed hydroponic system clearly indicate different cultivar responses. With cultivar ‘Star 1801’ the harvesting frequency seems not to be important, while a 14 day harvest frequency increased yield of cultivar ‘Fort Hook Giant’ significantly.

## Conclusion

Results demonstrate that Swiss chard cultivars respond differently to harvesting frequencies and plant densities. The highest yield was obtained with cultivar ‘Ford Hook Giant’ at a plant density of 40 plants/m$^2$ when plants were harvested on a biweekly basis. With the other cultivar included in the trial, ‘Star 1801’, harvesting frequency had no significant effect on yield. It should be noted that the trial was conducted in a closed hydroponic system and cultivars might perform differently in other cultivation systems, such as soil cultivation.

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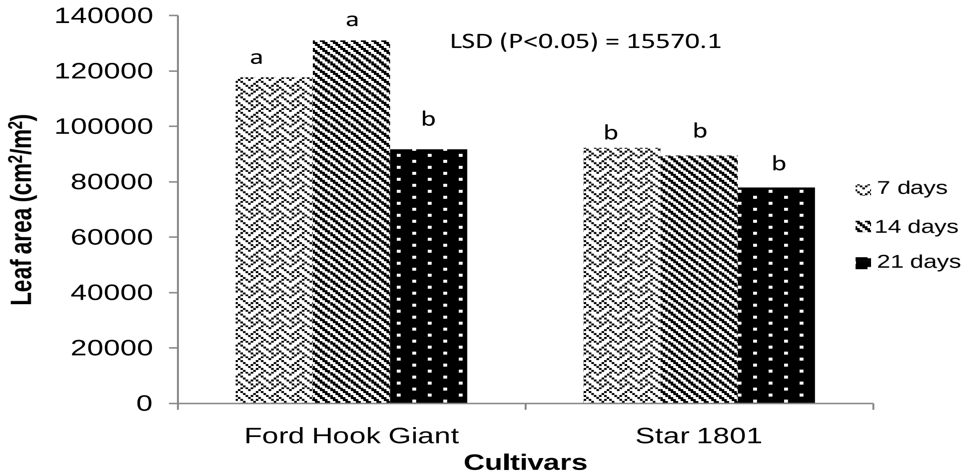


**Figure 7**. Interaction effect of harvesting frequencies and cultivars on leaf area. Columns with different letters denote significant difference at the 5% level.

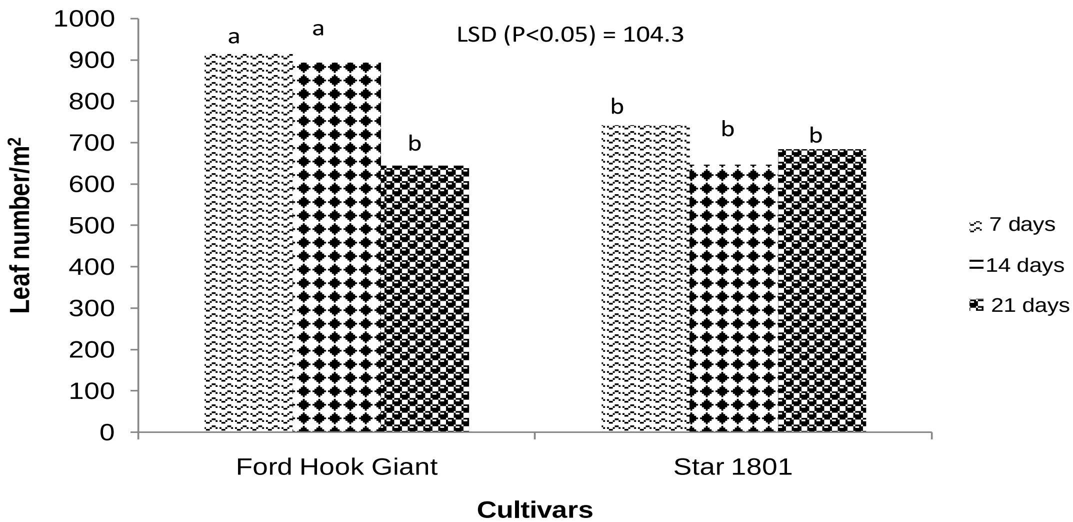


**Figure 8.** Interaction effect of harvesting frequencies and cultivars on leaf number. Columns with different letters denote significant difference at the 5% level.

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