Effect of different spacing on the growth and yield of California Wonder Bell Pepper (*Capsicum annuum*) on well drained sandy loam soil in The Gambia.

ABSTRACT

Optimum plant spacing ensures proper growth and development of crops resulting in maximum crop yield and economic use of land. The objective of this study was to evaluate the effects of different planting spacing on the growth and yield of California Wonder Bell Pepper (*Capsicum annuum*) on well drained sandy loam soil of The Gambia. The design used for this experiment was a Randomized Complete Block Design (RCBD) with four treatments (T1: 50 x 50 cm, T2: 50 x 40 cm, T3: 50 x 30 cm and T4: 50 x 20 cm) and three repetitions and the parameter of plant height, stem girth, number of leaves, fruit length, fruit circumference, individual fruit weight, yield per plant, and yield per hectare. The plant spacing had significant effect on plant height, stem girth and number of leaves of the growth parameters, whereas for the yield parameters, individual fruit weight, yield per plant and total biomass yield were found significantly in treatments with the highest plant spacing (50 x 50 cm). In conclusion, wider plant spacings encourage the plants to develop the maximum number of branches and fruits.
Key words: Effect, Fruit, Number, Parameters, Crop

1. INTRODUCTION

Pepper (*Capsicum annuum* L.) is an annual herbaceous plant belonging to the *Solanaceae* family, which is cultivated in warm climate, such as Asia, northern America, southern and central Europe, and tropical and subtropical Africa (Baenas *et al.*, 2019). Pepper is one of the most important agricultural vegetable crops all over the world, with a production of 34.5 million tonnes (MT) of fresh pepper and 3.9 MT of dry pepper (FAOSTAT, 2016). In the Gambia sweet pepper is a potential export crop and the fruits are use in soups, stews or eaten row in salad. Sweet pepper production in the Gambia is presently concentrated in the western part of the country where the climate is suitable for pepper production only when night temperature stays above 13°C as a big disparity (being unequal) in temperature cause the flower to fall off as well as very high temperature may cause infertile pollen and low fruit set (Joardder & Masud, 2019). Most cultivars of sweet pepper are adapted to temperatures in the range of 21-25°C. In order to grow and develop, sweet pepper requires good drainage of the soil as water logging will cause leaf shedding since the root system is particularly sensitive to water logging. It requires fertile loam or sandy soil of good drainage and rich in organic matter (Preedy, 2015).

Successful cultivation of any crop depends in several factors. Sowing date and plant spacing are one of the important aspects for production system of different crops. Optimum plant spacing ensures proper growth and development of plant resulting maximum yield of the crop and economic use of land. Yield of sweet pepper has been reported to be dependent on the number of plants accommodated per unit area of land (Islam et al., 2011). There are very few reports regarding the sowing date and spacing to cultivate sweet pepper under the agro-climatic conditions of The Gambia. According to Ahmad & Verma (2021); plant density determines the yield and quality of produce in any crop, optimum plant density could be achieved by establishing appropriate distance both between the rows as well as between the plants within a row. This determines competition among crop plants for minerals, nutrients and also important to facilitate aeration and light penetration into the crop canopy thereby affecting yield and quality of the produce.

In addition, few or no research has been done in The Gambia on the impact of different spacing on the growth and yield of sweet pepper. Hence, there is little available data for referencing and citation. This study seeks to fill that information gap in the country by making available the results obtained from this investigation to research institutions for referencing, and to vegetable garden growers to help improve their yields by adopting simple spacing techniques in The Gambia.

Considering the above facts, the main objective of this study is to determine the effect of different spacing on the growth and the yield of sweet pepper variety California wonder bell and evaluate which spacing techniques will response positively or negatively on the growth and the yield of sweet pepper.

2. MATERIALS AND METHODS

2.1 Study Area

The trial was conducted at The Gambia College school garden, Brikama town, Kombo Central District in West Coast Region. The experimental area is situated at latitude 13º 16' 16" North and longitude 16º 38' 57'' West. The site is located on a flat, well drained sandy loam soil with pH 6.0. The research was conducted in the dry season and source of water was from a tap located within the site.

2.2 Plant Material

The California Wonder pepper is a standard bell pepper that is widely adapted and it produces very sturdy frames that are easy to grow. This pepper always produces well formed, juicy, crunchy, large pepper fruits; this classic heirloom pepper has set the standard since the late 1920s.

3.3 Experimental Design, Treatments, Agronomic Practices and Growth Conditions

The design used for this experiment was a Randomized Complete Block Design (RCBD) with four treatments and three repetitions:

- Treatment 1 (**T1**): spacing of 50 x 50cm between the sweet peppers
- Treatment 2 (**T2**): spacing of 50 x 40cm between the sweet peppers
- Treatment 3 (**T3**): spacing of 50 x 30cm between the sweet peppers
- Treatment 3 (**T4**): spacing of 50 x 20cm between the sweet peppers

The California Wonder pepper were sown in drills 20 cm apart 2 cm deep and then covered lightly with soil, which was then compressed to remove air pocket. This was followed by the application of soft dry grasses on the surface of the seed bed for sterilisation with the aim of minimising the incidence of soil borne diseases such as damping off. The seedling spent four weeks after germination in the nursery bed before transplanting.

The experimental plots were demarcated in treatments and replicates. Each replicate was divided into three beds. Each bed had a wide of 1 m at a length of 3 m and 1 m between replicates and 50 cm between beds. The borders between beds and replicates were identified by wooden pegs. And plots were moistened ready for transplanting, the implements (tools) used were watering cans for watering, garden fork for turning the soil and rake for levelling of the plots.

Transplanting of sweet pepper seedling to the experimental plots was done by using a planting rope and when the seedlings were about four weeks after germination. Transplanting was done in the evening. And when the seedlings were fully established, the plants were watered twice a day (both morning and evening) until the soil was fully wet. Watering was carried out from this stage until the final harvest. Also, weeding was done manually by using a hand hoe. First weeding was carried out two weeks after transplanting. Second weeding was done two weeks after the first weeding and close to flowering whereby the plants are almost at their 50% flowering. Other weeding was done when it is necessary in order to loosen the soil. A hand hoe is used to turn the soil frequently. For organic and inorganic fertilisation, poultry manure was applied three weeks prior to transplanting as basal application at a rate of 3 kg per bed, so that it can decompose. A week after transplanting urea was applied at a rate of 60 g per bed as top dressing. NPK 15:15:15 was also applied three weeks after transplanting at a rate of 120 g per bed. These applications were done taking into account the soil sample analysis.

2.4 Soil Sample Analysis

Soil samples were sent to the laboratory of the National Agricultural Research Institute (NARI) located in Brikama (Gambia). The method of soil sample collection was carried out from one plot (treatment) in each replicates.

2.5 Variables

Five plants from each treatment were used randomly to collect the growth parameters and every plot was used for yield data collection.

2.6 Growth parameters
2.6.1 Plant height and Stem girth: The plant height and stem girth was determined with a measuring tape and digital Vernier Caliper.
2.6.2 Numbers of leaves: The numbers of leaves was also determined counting for each treatment and for each determine plant evaluated.
2.6.3 Yield parameters
Harvesting of the sweet pepper fruits was done started 65 days after transplanting. Ripe fruits were picked at an interval of every two weeks using knife tool (steel knife) and it was harvested three times.
2.6.4 Fruit Length (cm), Fruit Circumference (cm) and Individual Fruit Weight (g)
Fruit length, fruit circumference and individual fruit weight were measured during every harvest from each treatment. The fruit length was measured from the base of the fruit to tip with a measuring tape. While the fruit circumference was measured with the help of thread at a point of maximum thickness of fruit and the thread point were measures with measuring tape. On the other hand, a digital balance was used to measure the fruit weight.
2.6.5 Fruit number per plant: The amount of fruits harvested was counted and recoded for each plant.
2.6.6 Yield per hectare: The total yield was determined in ton per hectare for each treatment at the end of the harvest.

2.7 Statistical Analysis
Data were performed using SPSS STATISTIC Software Version 21.0 (IBM 2015) for Windows. The growth and yield data were analysed separately for each experiment and means were compared using student's T-test, and differences were compared at Tukey ($P \leq 0.05$).

3. RESULTS AND DISCUSSION
3.1 Soil Analysis
Table 1. Results of soil analysis from the Gambia College school garden.

Soil pH 1:2	EC (Mmhos/cm) 1:2	Organic Matter (%)	Sand (%)	Clay (%)	Silt (%)	Textural Class
6.0	3.0	1.10	66.2	9.04	24.7	Sandy loam

Table 1 presents the results from the soil analysis done from the samples collected and sent to the laboratory of the National Agricultural Research Institute (NARI) The Gambia. These results showed a high electric conductivity from the soil of the Gambia College school garden and a pH of acidity character. Result also showed that the soil from the Gambia College school garden is Sandy Loam with an adequate pH for the growth of bell pepper (Rokni et al., 2021).

3.2 Plant Height, Stem Girth and Number of leaves
The effect of plant spacing was found to be significant on plant height at seven weeks between the treatments. It was also found that treatments (T1) and (T2) were almost at the same height with of 42.3 and 42.7 centimeters respectively, followed by treatment (T4) with 39 centimetres and the plant with lowest plant height was obtained from treatment (T3) with a mean of 38.3 centimetres. With the regard to stem girth, the mean stand count of plant parameter showed significant difference in plant stem girth after final harvest between treatments. Treatment (T1) had the highest mean of 38.1 millimetres, followed by treatment (T2) which had a minimum of 35.9 millimeters and the lowest mean of 31.5 millimetres was recoded for treatment (T4). Meanwhile, the effect of spacing on leaves count at final harvest was found to be significant between treatments. The highest number of leaves was recorded in treatment three (T1) and treatment (T3) with an average of 116 leaves per plot (Table 2).

Table 2. Effect of different plant spacing on plant height, stem girth and number of leaves of the California wonder bell pepper.

Treatments	Plant Height (cm)	Stem girth (mm)	Number of Leaves
50cmx50cm (T1)	132.6 a	38.1 a	116 a
50cmx40cm (T2)	121.4 a	35.9 ab	106 b
50cmx30cm (T3)	118.6 b	33 ab	116 a
50cmx20cm (T4)	114.1 b	31.5 b	99 c

Different letter show the significantly different (P ≤ 0.05) using Turkey multiple range tests*.

With respect to the results of these findings, plant height at different growth stages of the California wonder bell pepper showed variations at different plant spacing. The findings of Edgar et al. (2017); between planting distance found that the highest plant were recorded in the treatment with the lowest planting distance. This increase in plant height in closer spacing can be explained from the fact that in case of higher population density, penetration of light was decreased which might have led to increase the endogenous auxins formation and enhanced the growth of the buds which due to competition tended to grow faster in order to outperform the next plant. The results of the present study for this parameter is also in agreement with previous findings by Worku & Astatkie, (2015) reported that plant height is determined by planting space which has a significant influence crop growth and development.

On the other hand, the results of the effect of plant spacing on stem girth during this study showed a statistically significant between the treatments registering the highest maximum stem girth of 38.1 cm in treatment (T1) with spacing (50x50 cm). These results coincided with the finding of Adetoro et al., (2021) reporting highest stem girth in plants with the widest spacing and it was gradually decreased with decreasing plant spacing where the lowest was recorded on the closest spacing.

Finally, the maximum number of leaves per plant (116) was recorded from treatment (T1). This results are in agreement with findings by Albaugh et al. (2020) reporting in higher plant densities can be observed lower number of leaves, branches and less canopy diameter. Other findings by Kaur et al. (2020) reported the minimum number of leaves per plant of green pepper was recorded from the closest spacing which was however statistically similar to the widest spacing. The measurements made on plant components show that more leaves were observed as plant population reduced probably in relation to lower competition for physical production resources (soil moisture and nutrients) which would enhance nutrient availability and efficient utilization of assimilates.

3.3 Fruit Length (cm), Fruit Circumference (cm) and Individual Fruit Weight (g)

Based on the results obtained and under the conditions in which the work was carried out, the plant spacing showed no effects on days to first harvest, fruit length, fruit circumference and individual fruit weight of the plant evaluated (Table. 3). That means there were no influence of the spacing between the sweet pepper those variables responded equals except the variable individual fruit weight where the best results were reported at treatments 1 and 2 (50 x 50 cm and 50 x 40 cm respectively) while treatments 3 and 4(50 x 30 cm and 50 x 20 cm respectively) the worst ones.

Table 3. Effects of the days to first harvest, fruit length, fruit circumference and individual fruit weight with on different planting space of the California wonder bell pepper.

Treatments	Days to First Harvest	Fruits Length (cm)	Fruit Circumference	Individual Fruit Weight (g)

			(cm)	
50cmx50cm (T1)	93a	7.67a	13a	39.87a
50cmx40cm (T2)	99a	8.00a	14a	40.03a
50cmx30cm (T3)	103a	7.67a	12a	36.34b
50cmx20cm (T4)	101a	7.89a	13a	37.2b

Different letter show the significantly different ($P \leq 0.05$) using Turkey multiple range tests*.

According to Pramanik et al. (2020); and Ganjare et al. (2013) wider plant spacing produce short and robust plant due to less competition between the plant for light, water, nutrients etc., but it may aggravate more weeds infestation. These results are in concordance with ours for the treatments 50 x 40 cm where we reported the best individual fruit weight. In case of closer plant spacing results in taller plants produced due to heavy competition among plants for natural resources but the weeds population is comparatively less. Generally, high density method is adopted in greenhouse for efficient use of natural resources and inputs to increase productivity. Resources such as water, nutrients, space and light are effectively utilized by better root spread in wider spacing.

3.4 Number of Fruits/Plant
The result in Fig. 1 has shown significant difference in number of fruits per plant at final harvest between treatments, of which the treatment (T2) had the highest in number of fruits per plant. Followed by treatment (T1) and treatment (T3), with the lowest in number of fruits per plant been recorded for treatment (T4). The results showed that vegetative yield characteristics such as number of fruits and plant total yield increased with increasing plant density.
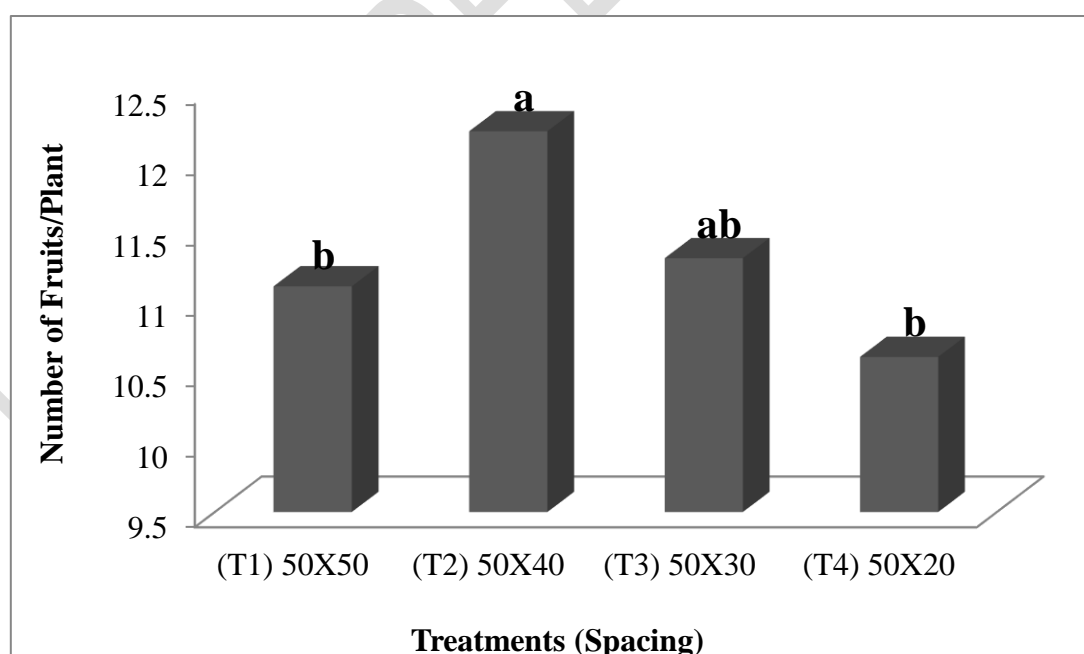

Figure 1. Effect of different plant spacing on number of fruits per plant of the California Wonder Bell Pepper obtained from the four treatments evaluated. Different letter show the significantly different ($P \leq 0.05$) using Turkey multiple range tests*.

The result of the present study is in agreement with the findings of Khasmakhi-Sabet et al. (2009) who reported that yield increased as plant density increases. The highest density produced the highest fruit yield while the lowest yield per hectare was recorded at lower density. The greatest fruit yield of sweet pepper plants were obtained from plants grown at high density.

3.5 Yield Total ton/ha

Effects of plant spacing were found to be significant on yield total per hectare at final harvest. The closest spacing (50x20 cm) produced the tallest and weakest plants resulting to the lowest yields. The highest yield at final harvest was recorded from treatment (T1) with a sum of 30 ton/ha. The second highest fruit yield obtained from treatment (T2) with a sum of 28 ton/ha fruits (Fig. 2).
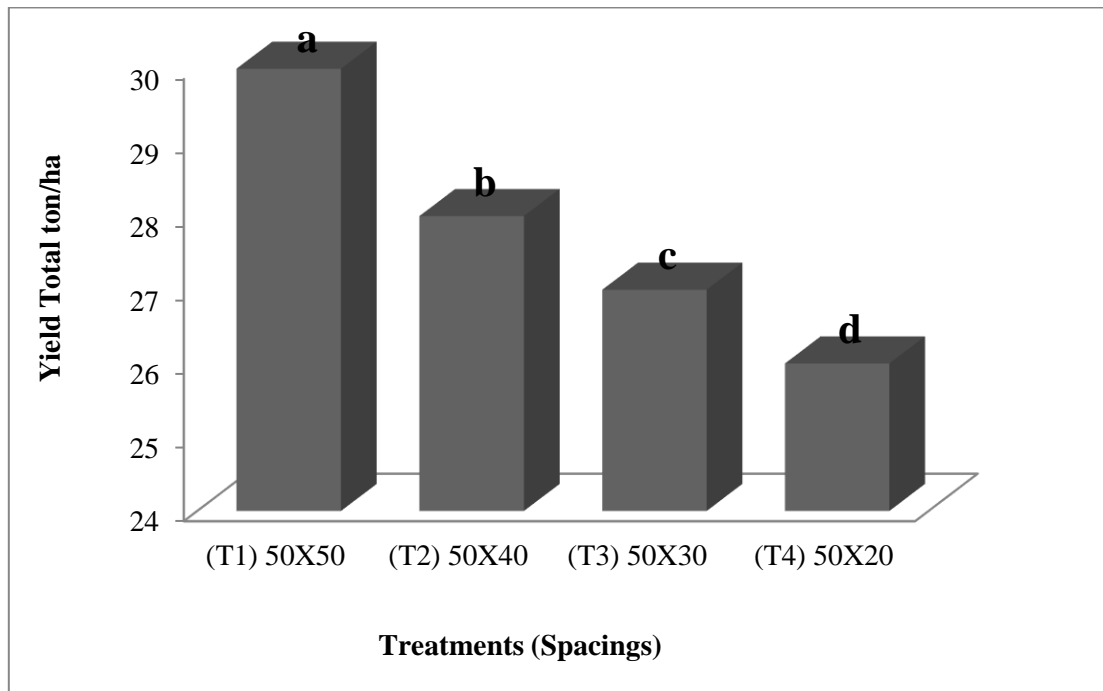

Figure 2. Results of the different plant spacing on total yield of the California Wonder Bell Pepper after the final harvest. Different letter show the significantly different (P ≤ 0.05) using Turkey multiple range tests*.

The result above shown that treatment (T1) had the highest fruit weight and improved yield parameters than any other treatments, this is because the higher population density reduced yield per plant might be attributed to lesser fruit yield per plant. The lower plant population densities produced more vigorous crops than at higher population densities but this could not compensate for the small number of plants per unit area. According to Du et al. (2021) the use low population densities which is achieved by higher plant spacing but cumulative yield per hectare was higher at high population density under low plant spacing. Findings by Sharma & Kumar, (2017) reported that plant spacing had significant variation in almost all the growth and yield components Number of branches/plant, number of fruits/plant, and yield/plant were increased with the increasing of plant spacing but plant height was found to be significantly increased with the decreasing plant spacing. The lower in the yield per hectare in the high population density under low plant spacing could be seen associated to the competition for available water and mineral nutrients from the soil and light is greater at high plant population densities and environmental factors, especially light intensity, stimulate the process of photosynthesis which in turn affected the stem circumference and is generally closely associated with plant growth rate and yield.

4. CONCLUSIONS

In conclusion, from the finding of this study, it could be concluded that treatment (T1) contribute significantly in terms of growth and yield parameters in well drained sandy loam soil during this research. This can be attributed to that in close spacing, stronger plants will outgrow the weaker plants and the latter will not grow well or even die which will affect your harvest. The right plant spacing will help to reduce competition for the sunlight that is vital to growth and will also help to conserve water by keeping the soil around the plants shaded. However, in term of growth parameters like plant height and stem girth, treatment (T1) and treatment (T2) perform better compare to the treatment (T3) and Treatment (T4), while treatment (T3) have had more effects on the number of leaves.

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