Short communication

Effect of different spacing on the growth and yield of California Wonder Bell Pepper (*Capsicum annuum*) on 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 sandy loam soil of The Gambia, from January to May 2018. 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 a significant effect on plant height, stem girth and the 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 spacing (50 x 50 cm) boosts the plants to develop the maximum number of branches and fruits.

Keywords: *Fruit, Number, Parameters, Pepper, Crop*

1. INTRODUCTION

Pepper (*Capsicum annuum* L.) is an annual herbaceous plant belonging to the *Solanaceae* family, which is cultivated in warm climates, 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 used in soups, stews or eaten raw in a 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^{o}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^{o}C. In order to grow and develop, sweet pepper requires good drainage of the soil as waterlogging will cause leaf shedding since the root system is particularly sensitive to waterlogging. It requires fertile loam or sandy soil of good drainage and rich in organic matter (Preedy, 2015).

Successful cultivation of any crop depends on several factors. Sowing date and plant spacing are important aspects of the production system of different crops. Optimum plant spacing ensures proper growth and development of plant resulting in a maximum the 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 the 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 respond positively or negatively to 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 Region is sub-tropical climate with average temperatures between 29°C and 34°C and with average annual rainfall ranging from 920 mm (36.2 in) to 1,450 mm (57.1 in). The site is located on a flat, sandy loam soil with pH 6.0. The research was conducted in the dry season and the source of water was from a tap located within the site.

2.2Plant 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 was sown in drills 20 cm apart 2 cm deep and then covered lightly with soil, which was then compressed to remove the air pocket. This was followed by the application of soft dry grasses on the surface of the seedbed for sterilization to minimize the incidence of soil-borne diseases such as damping off. The seedling preparation was done during the first week January and the seedlings 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 leveling 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. The second weeding was done two weeks after the first weeding and close to flowering whereby the plants are almost at their 50% flowering. Another 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 fertilization, poultry manure was applied three weeks prior to transplanting a 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 a 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 replicate.

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 were also determined counting for each treatment and for each determined 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 a 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 the 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 measured 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 number of fruits harvested was counted and recorded 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 analyzed 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, this is 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 centimeters. With the regard to stem girth, the mean stand count of plant parameter showed a significant difference in plant stem girth after final harvest between treatments. Treatment (T1) had the highest mean of 38.1 millimeters, followed by treatment (T2) which had a minimum of 35.9 millimeters and the lowest mean of 31.5

millimeters was recorded 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]

Values associated to different letters are significantly different (P = 0.05) according to Tukey's multiple range test*.

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 Oloniruha et al. (2021); Rajput et al. (2020); Edgar et al. (2017); between planting distance found that the highest plant was recorded in the treatment with the lowest planting distance. This increase in plant height in closer spacing can be explained by the fact that the case of higher population density, penetration of light was decreased which might have led to increasing the formation of the endogenous auxin and enhanced the growth of the buds which due to competition tended to grow faster in order to outperform the next plant. In addition, Mahdi et al. (2021) found that the application of potassium humate with the medium planting density (20 × 60 cm) was the best treatment combination to enhance the performance and productivity (2.97 ton ha^{-1}) of faba bean (*Vicia faba* L.) plants grown under newly reclaimed soil conditions.

The results of the present study for this parameter are also in agreement with previous findings by Worku & Astatkie, (2015); Hussein & Hussein (2021); reported that plant height is determined by planting space which has a significant influence on 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 the 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). These results are in agreement with findings by Albaugh et al. (2020) reporting in higher plant densities can be observed a 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 was no influence on 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 (cm)	Individual Fruit Weight (g)

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

Values associated to different letters are significantly different (P = 0.05) according to Tukey's multiple range test*.

According to Pramanik et al. (2020); and Ganjare et al. (2013) wider plant spacing produce a 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 a 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 a significant difference in the number of fruits per plant at final harvest between treatments, of which the treatment (T2) had the highest in the number of fruits per plant. Followed by treatment (T1) and treatment (T3), with the lowest in the number of fruits per plant been recorded for treatment (T4). The results showed that vegetative yield characteristics such as the number of fruits and plant total yield increased with increasing plant density.

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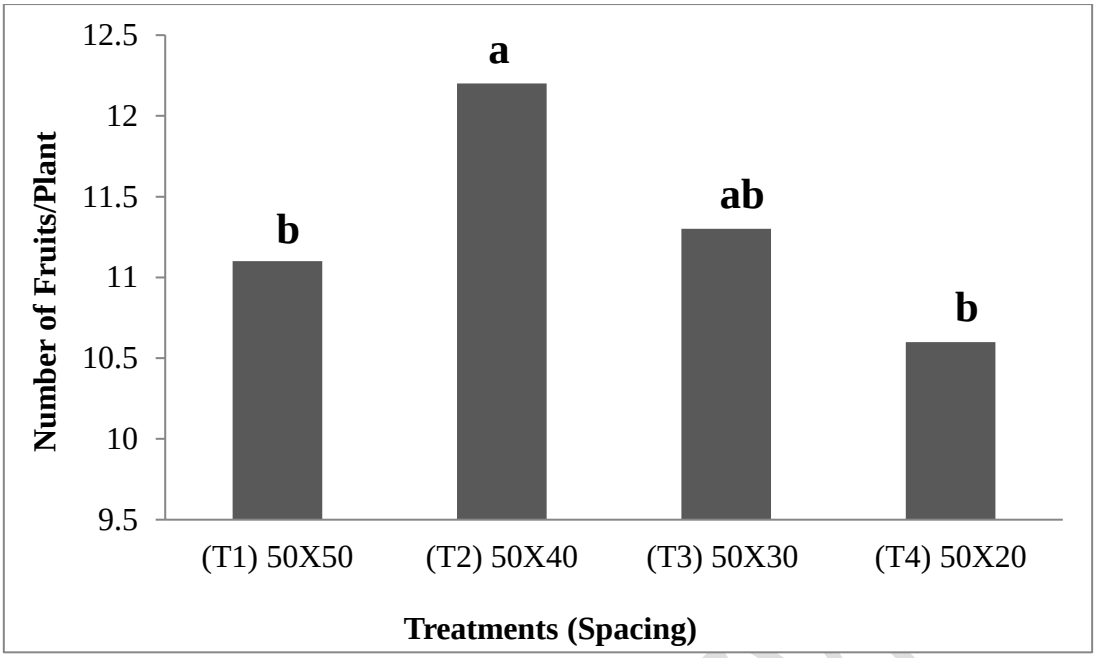

Figure 1. Effect of different plant spacing on the number of fruits per plant of the California Wonder Bell Pepper obtained from the four treatments evaluated. Values associated to different letters are significantly different (P = 0.05) according to Tukey's multiple range test*.

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 lowest density. The greatest fruit yield of sweet pepper plants was obtained from plants grown at high density. However our results are not in agreement with the findings of Sandhu et al. (2021) who reported that bell pepper plants were more sensitive to interspecific competition, whereas tomato plants were more sensitive to intraspecific competition. In addition, they do not recommended high plant density. López-Ramos et al. (2021) reported that high planting density caused smaller stems diameter and higher yield per m^{-2} for Husk tomato (*Physalis ixocarpa* Brot.) in field and greenhouse.

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 the lowest yields. The highest yield at harvest was recorded from treatment (T1) with a sum of 30 t/ha. The second highest fruit yield was obtained from treatment (T2) with a sum of 28 ton/ha fruits (Fig. 2).

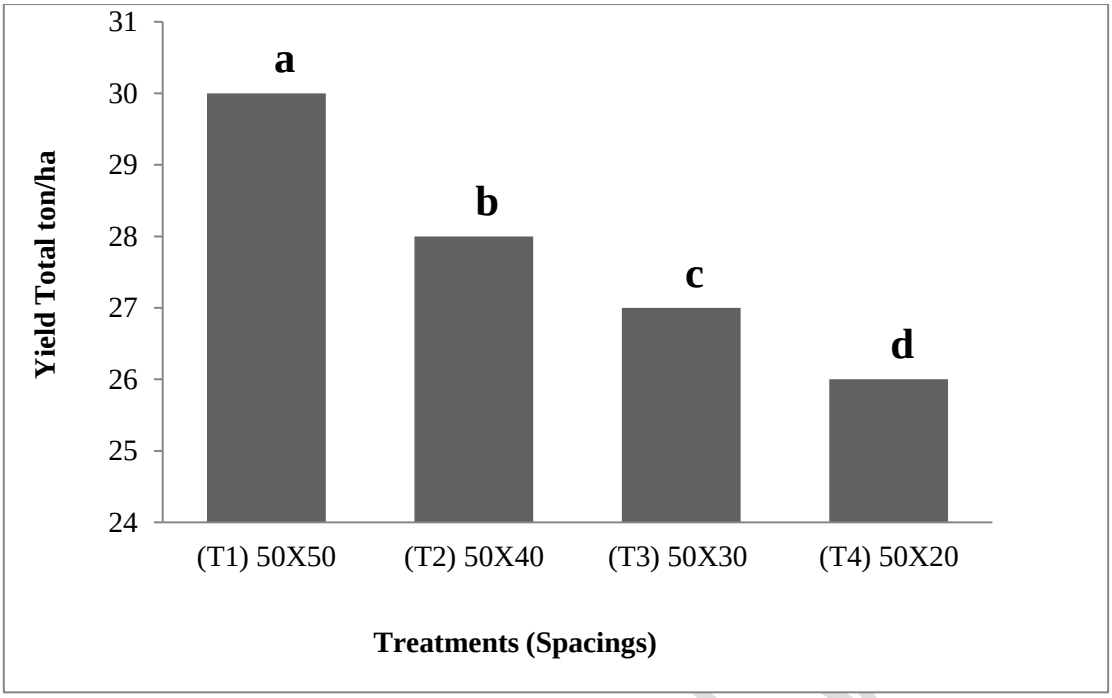

Figure 2. Results of the different plant spacing on the total yield of the California Wonder Bell Pepper after the final harvest. Values associated to different letters are significantly different (P = 0.05) according to Tukey's multiple range test*.

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 of low population densities 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, the number of branches/plant, the 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 with 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

From the finding of this study, it could be concluded that treatment (T1) contributes significantly in terms of growth and yield parameters in 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 for 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.

REFERENCES

1. Adetoro, NA, Oworu, OO, Nassir, AL, Bello, A, Parkes, E, Ogunbayo, SA, & Kulakow, P. Evaluation of improved cassava genotypes for yield and related traits for a better breeding strategy under different agroecologies in Nigeria. *Euphytica*, 2021. *217*(4), 1-19. https://doi.org/10.1007/s10681-021-02798-9
2. Ahmad, F & Verma, DMR. Effect of mulching and planting density on production of sweet banana pepper (*Capsicum annuum* L.). *IJCS*, 2021. *9*(1), 1373-1378. https://doi.org/10.22271/chemi.2021.v9.i1t.11413
3. Alam, MS, Saha SR, Salam MA, Alam, MS, and Alam MK. Effect of sowing time and plant spacing on the yield and yield attributes of sweet pepper (*Capsicum annuum.* Bangladesh J. Agril. Res. 2011. 36(1): 271-278.
4. Albaugh, TJ, Maier, C. Campoe, OC, Yáñez, MA, Carbaugh, ED, Carter, DR, & Fox, TR. Crown architecture, crown leaf area distribution, and individual tree growth efficiency vary across site, genetic entry, and planting density. *Trees*, 2020. *34*(1), 73-88. https://doi.org/10.1007/s00468-019-01898-3
5. Baenas, N, Belović, M, Ilic, N, Moreno, DA, & García, VC. Industrial use of pepper (*Capsicum annum* L.) derived products: *Technological benefits and biological advantages. Food chemistry*, 2019. 27(4), 872-885. https://doi.org/10.1016/j.foodchem.2018.09.047
6. Du, X, Wang, Z, Lei, W, & Kong, L. Increased planting density combined with reduced nitrogen rate to achieve high yield in maize. *Scientific Reports*, 2021. *11*(1), 1-12.
7. Edgar, ON, Gweyi-Onyango, JP, & Korir, NK. Plant row spacing effect on growth and yield of green pepper (*Capsicum annuum* L.) in Western Kenya. *Archives of Current Research International*, 2017. 1-9. doi: 10.9734/ACRI/2017/33101

8. FAOSTAT Food and agriculture organization of the United Nations. FAOSTAT. Statistics Database. 2016. Accessed 31.03.2021.
9. Ganjare H, Futane NW, Dagwar S, Kurhade K. Growth and yield characters of *capsicum* in response to planting distance and sources of nutrients. Scholarly Journal of Agricultural Science. 2013;3(9):386-390.
10. Hossein M, Hossein, Atefe A, and Hamide F. Effect of plant density and nitrogen fertilizer on growth, yield and fruit quality of sweet pepper *Capsicum annum* L.) African Journal of Agricultural Research. 2012. Vol. 7:(6), Pp. 859-866.
11. Hussein, S. Q., & Hussein, A. K. (2021). Effect of Plant Densities on Some Growth Traits of Varieties of Sorghum (*Sorghum Bicolor* (L) Moench). Annals of the Romanian Society for Cell Biology, 4455-4463.
12. Islam M, SAHA S, Hasanuzzaman MD. AK, Rahim M. Effect of spacing on the growth and yield of sweet pepper (*Capsicum annuum* L.). Journal of Central European Agriculture. 2011. 12 :(2), Pp.328-335.
13. Joardder, MU, & Masud, MH. *Food Preservation in Developing Countries: Challenges and Solutions*. Springer. 2019.
14. Kaur, P, Singh, SK, Kaur, R & Sidhu, MK. Response of Different Levels of Nitrogen and Spacing on Growth and Yield of Cauliflower Grown under Central Region of Punjab. *International Journal of Bio-resource and Stress Management*. 2020. https://doi.org/10.22271/chemi.2021.v9.i1t.11413
15. Khasmakhi-Sabet A, Sedaghathoor Sh, Mohammady J, Olfati A. Effect of plant density on Bell pepper yield and quality. Int. J. Veg. Sci., 2009. 15: 264-271.
16. López-Ramos, B. I., Ortiz-Hernández, Y. D., Morales, I., & Aquino-Bolaños, T. (2021). Plant density on yield of Husk tomato (*Physalis ixocarpa* Brot.) in field and greenhouse. Ciência Rural, 51(1).
17. Mahdi, A. H., Badawy, S. A., Abdel Latef, A. A. H., El Hosary, A. A., Abd El Razek, U. A., & Taha, R. S. (2021). Integrated effects of potassium humate and planting density on growth, physiological traits and yield of *Vicia faba* L. grown in newly reclaimed soil. Agronomy, 11(3), 461.
18. Ngozi E.A and Chidera V. The effect of plant density on growth and yield of 'NsukkaYellow' aromatic pepper (*Capsicum annuum* L.). Afr. J. Agric. Res.2012. Vol. 12: (15), Pp. 1269-1277.
19. Oloniruha, J. A., Ogundare, S. K., & Olajide, K. (2021). Growth and yield of Sesame (*Sesamum indicum*) as influenced by plant population density and organo-mineral fertilizer rates. Agro-Science, 20(1), 15-21.
20. Pramanik, K, Mohapatra, PP, Pradhan, J, Acharya, LK, & Jena, C. Factors Influencing Performance of Capsicum under Protected Cultivation: A Review. 2020. 10(12): 572-588

21. Preedy, VR. (Ed.). Essential oils in food preservation, flavor and safety. Academic Press. 2015.
22. Rajput, V., Abhishek Kumar, J., & Tomar, S. Effect of pinching and spacing on growth parameters of African marigold (*Tagets erecta* L.). Plant archives 2020c, 20, 533-37.
23. Rokni, N, Alizadeh, HS, Bazgir, E, Darvishnia, M & Mirzaee, H. The tripartite consortium of *Serendipita indica*, *Trichoderma simmonsii*, and bell pepper (*Capsicum annum*). *Biological Control*, 2021. 104608.
24. Sandhu, R. K., Boyd, N. S., Zotarelli, L., Agehara, S., & Peres, N. (2021). Effect of Planting Density on the Yield and Growth of Intercropped Tomatoes and Peppers in Florida. HortScience, 1(aop), 1-5.
25. Sharma, R & Kumar, R. Growth, flowering and yield of chilli, (*Capsicum annuum* L.) as influenced by spacing and growing conditions. *Int. J. Pure App. Biosci*, 2017. *5*(5), 524-527. http://dx.doi.org/10.18782/2320-7051.5858
26. Worku, M & Astatkie, T. Effects of row spacing on productivity and nodulation of two soybean varieties under hot sub-moist tropical conditions in south-western Ethiopia. Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS). 2015. 116(2), 99-106.