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Effect of planting density and fruit load on flowering, fruit set and yield of custard apple

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Abstract
An investigation was carried out to study the "Effect of planting density and fruit load on fruit yield and quality of custard apple." The experiment was laid out in Factorial Randomized Block Design with three spacing levels 4 x 4 m, 4 x 2.5 m and 3 x 3 m and five levels of fruit load (fruit retention). Fruit retention up to 100 per plant, Fruit retention up to 80/plant, Fruit retention up to 60 per plant, Fruit retention up to40 per plant and No fruit thinning (control)fifteen treatment combinations replicated thrice. The fruit retention in varying quantities as per treatments was imposed after 15 days from fruit development when fruits were anola size. It is evident from the experimental findings that, in terms plant height was found highest under the treatment spacing 4 x 2.5 m as well as fruit retention 60 per plant. Whereas, the plant spread and plant volume under the treatment spacing 4 x 4 m as well as fruit retention 60 per plant. The flowering time in terms of days from pruning to first flower bud initiation was observed in the treatment spacing 4 x 4 m as well as fruit retention 60 per plant. Leaf area and chlorophyll contents were observed in the treatment spacing 4 x 2.5 m as well as fruit retention 60 per plant. The fruit yield parameters like number of graded fruits per plant and weight of fruits found highest under the treatment spacing 4 x 2.5 m as well as fruit retention 60 per plant.

Keywords: Spacing, fruit load, plant density, pruning, thinning, flowering, yield

Introduction

Custard apple (*Annona squamosa* L.) a native of tropical America is the most favourable fruit crop in India under the family Annonaceae and has got a pleasant flavour, mild aroma and sweet taste which have a universal acceptance. It is popular by virtue of its spontaneous spread in forest, waste lands, rocky slope and other uncultivated places, its nutritional value and wide uses in processing industries as well as in manufacturing bio-pesticides. Custard apple is an arid fruit crop and hardy in nature requires dry climate with mild winter. It is proving boon to the arid zones of Maharashtra because of their wider adaptability, comparatively freeness from pests and diseases, hardy nature, known to thrive under diverse soil and climatic conditions and also escape from stray and grazing animals. Custard apple is one of the finest fruits gifted to India by tropical America and West Indies. In India, the custard apples are very popular in Deccan plateau and are grown commercially on smaller scale in Andhra Pradesh, Bihar, Madhya Pradesh, Maharashtra, Uttar Pradesh, Tamil Nadu, Assam, Karnataka and Orissa. Maharashtra and Andhra Pradesh are the leading states in Annona cultivation as well as annual production. In 2017, the area and production of custard apple in Maharashtra is (9,424 Ha), (65,968 Mt) respectively which is 64.45 per cent of total area and 64.49 per cent of total production in India (Hiwale, 2015) [13]. The productivity of custard apple in Maharashtra is 2.87 production / Ha (Anonymous, 2015) [3].

Due to large tree canopy, the traditional system of custard apple cultivation has often posed problems in obtaining desired fruit productivity per unit area. Therefore, there is need of changing production system in custard apple by manipulating its natural plant canopies. Currently, there is a worldwide trend of higher density planting to control tree size and maintained desired architecture for higher productivity. Better light interception and improved microclimatic conditions in the orchard and within the plant canopy not only improved the productivity but improves the quality of fruit and reduce the stress of pest and disease. So, that the high density recharging facilitates enhance production and quality of fruits by managing the plant canopies in the different ways. There is a shift in farmers' insight from production to productivity and profitability which can be achieved through high density planting. Recently, there is a trend to plant fruit trees at closer spacing leading to high density orchard.

Now a day's high-density planting is a new approach in custard apple cultivation in Maharashtra. The traditional cultivation of custard apple was made on 6 x 6 m or 5 x 5 m wide spacing but due to high density planting the farmers of Vidarbha is planting their custard apple orchard on 4 x 4 m, 4 x 3 m, 3 x 3 m and 4 x 2.5 m. There are good growth and better fruiting in close spacing along with summer pruning having drip irrigation. Due to high density planting fruit yield per unit area is more in custard apple (Anonymous, 2018) [4]. HDP results in overcrowding, over lapping not only in the tops, but also in the root system and heavy competition for space, nutrients and water. It induces precocity, increases yield and improves fruit quality.

Thinning increases fruit size, Increases the annual yield of marketable fruit, improve the colour of fruit, improve the quality of fruit (T.S.S), fetching good market price reduces the limb breakage and promotes general tree vigor and ensure more regular cropping. For production of economical yield of custard apple fruits, it is necessary to adopt a proper agro-technique by applying new cultural practices like standard cultural practices, training, pruning, thinning, growth regulators, nutrition, plant density etc. are most important for production of vegetative growth, flowering, fruit yield and quality yield. The growth and flowering of Custard apple are greatly influenced by different spacing and fruit load like 60 fruits per plant and 80 fruits per plant.

Materials and Methods

The field experiment entitled "Effect of planting density and fruit load on fruit yield and quality of custard apple" cv. Balanagar was conducted at farmers field during the year 2018-19 and 2019-20. And analytical work of the experiment was carried out at Analytical Laboratory, Department of Fruit Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the year 2018-19 and 2019-20. Ten-year-old custard apple healthy plants of uniform growth of cultivar Balanagar were selected from the custard apple plantation for experimentation.

The experiment was conducted in Factorial Randomized Block Design (FRBD) with 15 treatment combination which were replicated thrice and number of plants per treatment was five. The custard apple orchard was well established which was planted before ten years at different spacing in different block of the same field. The spacing of the custard apple blocks are S1: 4.0 m x 4.0 m, S2: 3.0 m x 3.0 m and S3: 4.0 m x 2.5 m while thinning or fruit retention per plot asT_1: Fruit retention up to 100/plant, T_2: Fruit retention up to 80/plant, T_3: Fruit retention up to 60/plant, T_4: Fruit retention up to40/plant and T_5: No fruit thinning. The custard apple field irrigated regularly during the period of investigation. The irrigation schedule was suggested as per the critical water requirements period of crop i.e., of flowering, fruit setting and fruit development stage.1st irrigation was given at flowering in the 1st week of July. Ploughing was done to break the dormancy and to keep up the soil loose and check weed growth in root. The custard apple field was kept weed free by regular weeding and also with the help of tractor operated tractor moulded implements. Fertigation schedule was followed during both the years of experimentation. Pruning was done in the last week of May, spraying of Boudreaux mixture after pruning was done. The growth hormones NAA was sprayed for control the flower and fruit dropping in the month July and August. Thinning was done when custard apple fruits had attained anola size and it was done as per the treatment combination in the first week of September. Five plants of each treatment were selected, marked and kept under observations for recording various observations. The detail observations recorded from planting spacing and fruit load.

Results and Discussion

The result obtained from present investigation are presented below on the basis on the pooled mean of two year of experimentation

Yield and yield attributing parameters

The observations regarding the effect of planting density and fruit load on fruit yield and quality of custard apple *viz*., number of flowers per shoot, flowering time, fruit set, total number of fruits per plant, fruit yield per plant, fruit yield per plant and fruit yield per hectare are presented in Tables 1 and 2.

Effect of plant density on number of flowers per shoot

Data presented in Table 1 revealed that, significantly highest number of flowers per shoot were noticed in spacing 4.0 x 4.0 m (16.91 and 17.12) followed by spacing 4.0 x 2.5 m (16.00 and 16.26). However, lowest number of flowers per shoot were noticed in spacing 3.0 x 3.0 m (14.41and 14.59) during both the years of experimentation.

Similarly, on the basis of mean pooled data it is revealed that significantly highest number of flowers per shoot were noticed in spacing 4.0 x 4.0 m (17.02) followed by spacing 4.0 x 2.5 m (16.13). However, lowest number of flowers per shoot were noticed in spacing 3.0 x 3.0 m (14.50).

Maximum number of flowers per shoot was observed in wider spacing as compared to closer spacing. More number of flowers in wider spacing might be due to a greater number of new shoots and larger leaf area which results in higher photosynthetic activity and accumulation of more photosynthates. The above results are in conformity with the findings of Shanti Lal *et al.* (1996) [22] in guava.

Maximum number of flowers on 60 fruit loads might be due to a greater number of new shoots that promote the development of new leaves in the axils of which flowers develop, whereas in heavy fruit load plant the number of new shoots is less which therefore produce fewer flower buds. The above results are in conformity with the findings of Zora Singh and Sandhu (1984) [26].

Effect of fruit load on number of flowers per shoot

Data presented in Table 1 revealed that, significantly highest number of flowers per shoot were noticed in the treatment fruit retention 60 per plant (17.94 and 18.25) which were found superior than other treatments followed by the treatment fruit retention 80 per plant (16.56 and 16.79), the treatment fruit retention 100 per plant (15.40 and 15.57) and the treatment fruit retention 40 per plant (15.33 and 15.50). However, lowest number of flowers per shoot were noticed in the treatment no fruit thinning (13.63 and 13.84) during both the years of experimentation.

Similarly, on the basis of mean pooled data it is revealed that significantly highest number of flowers per shoot were noticed in the treatment fruit retention 60 per plant (18.10) which were found superior than other treatments followed by the treatment fruit retention 80 per plant (16.67), the treatment fruit retention 100 per plant (15.48) and the treatment fruit retention 40 per plant (15.41). However, lowest number of flowers per shoot were noticed in the treatment no fruit thinning (13.74) during both the years of experimentation.

Maximum number of flowers per shoot was observed in wider spacing as compared to closer spacing. More number of flowers in wider spacing might be due to more number of new shoots and larger leaf area which results in higher photosynthetic activity and accumulation of more photosynthates. The above results are in conformity with the findings of Shanti Lal *et al.* (1996) [22] in guava.

Maximum number of flowers on 60 fruit loads might be due to a greater number of new shoots that promote the development of new leaves in the axils of which flowers develop, whereas in heavy fruit load plant the number of new shoots is less which therefore produce fewer flower buds.

The above results are in conformity with the findings of Zora Singh and Sandhu (1984) [26].

Interaction effect

Data presented in Table 1 revealed that, significantly highest number of flowers per shoot were noticed in the spacing 4 x 4 m with the treatment fruit retention 60 per plant S1T3 (19.80 and 19.97) which were found superior than other treatments followed by spacing 4 x 2.5 m with treatment fruit retention 60 per plant S2T3 (18.32 and 18.74) and spacing 4 x 4 m with the treatment fruit retention 80 per plant S1T2 (17.76 and 18.02)while lowest number of flowers per shoot were noticed in the spacing 3 x 3 m with the treatment no fruit thinning S3T5 (12.73 and 12.89) during both the years of experimentation. Meanwhile, the number of flowers per shoot were noticed in the spacing 4 x 4 m with the treatment fruit retention 100 per plant S1T1 (14.10 and 14.37) and spacing 4 x 2.5 m with 80 fruit retention S2T2 (17.76 and 18.02) were found at par. Also, S1T4, S2T4 and S3T3 were found at par.

Similarly, on the basis of mean pooled data it is revealed that, significantly highest number of flowers per shoot were noticed in the spacing 4 x 4 m with the treatment fruit retention 60 per plant S1T3 (1988) which were found superior than other treatments followed by spacing 4 x 2.5 m with treatment fruit retention 60 per plant S2T3 (18.53) and spacing 4 x 4 m with the treatment fruit retention 80 per plant S1T2 (17.89) while lowest number of flowers per shoot were noticed in the spacing 3 x 3 m with the treatment no fruit thinning S3T5 (12.81). Meanwhile, the number of flowers per shoot were noticed in the spacing 4 x 4 m with the treatment fruit retention 100 per plant S1T1 (16.72) and spacing 4 x 2.5 m with 80 fruit retention S2T2 (16.97) were found at par. Also, S1T4, S2T4 and S3T3 were found at par.

Maximum number of flowers per shoot was observed in wider spacing as compared to closer spacing. More number of flowers in wider spacing might be due to more number of new shoots and larger leaf area which results in higher photosynthetic activity and accumulation of more photosynthates. The above results are in conformity with the findings of Shanti Lal *et al.* (1996) [22] in guava.

Maximum number of flowers on 60 fruit loads might be due to more number of new shoots that promote the development of new leaves in the axils of which flowers develop, whereas in heavy fruit load plant the number of new shoots is less which therefore produce fewer flower buds.

The above results are in conformity with the findings of Zora Singh and Sandhu (1984) [26].

Effect of plant density on flowering time

The results regarding flowering time (in days from pruning) are presented in Table 1. The data revealed that the spacing 4 x 2.5 m recorded minimum flowering time in days from pruning (32.40 days and 33.53 days) which was significantly superior and statistically at par with the spacing 4 x 4 m (33.00 days and 34.07 days) during the year 2019 and 2020. However, significantly maximum flowering time in days from pruning (34.60days and 35.20 days) was recorded by the spacing 3 x 3 m.

Similarly pooled mean of two years data for flowering time from pruning (32.97 days) was recorded in spacing 4 x 2.5 m which was significantly superior and statistically at par with the spacing 4 x 4 m (33.53 days).

The early flowering might be due to high density planting which stimulates flowering and fruit production as availability of nutrients are in sufficient quantities of the plant to carry out their metabolic and physiological processes. These findings are in accordance with results reported by Patil (1987) [19] in Ber and Adhikari *et al.*, (2015) [2] in Kagzi lime.

Effect of fruit load on flowering time

The results regarding effect of fruit load on flowering time (in days from pruning) are presented in Table 1. The data revealed that, the treatment fruit retention 60 per plant recorded minimum flowering time in days from pruning (32.00 days and 32.89 days) which was significantly superior and statistically at par with the treatment fruit retention 80 per plant and fruit retention 100 per plant during the year 2019 and 2020. Also, the treatment fruit retention 40 per plant recorded at par with the treatment no fruit thinning.

Similarly pooled mean of two-year data for lowest flowering time in days from pruning (32.44 days) was recorded in treatment fruit retention 60 per plant which was significantly superior and statistically at par with the treatment fruit retention 80 per plant (32.72 days) and fruit retention 100 per plant (33.67 days). However, significantly highest flowering time in days from pruning (35.72 days) was observed in the treatment no fruit thinning which was statistically at par with the treatment fruit retention 40 per plant (34.44 days).

Heavy fruit load trees initiate flowering later as comparison to light fruit load trees and the new vegetative growth was delayed. Low fruit load trees started new vegetative growth immediately and almost the entire amount of carbohydrates, which otherwise would form flower buds, might have been utilized in the vegetative growth of trees resulting in a delayed flowering low fruit load trees (Dhaliwal and Singh 2004) in guava.

Interaction effect

The results regarding flowering time (in days from pruning) are presented in Table 1. The data presented in Table 8 revealed that, an interaction effect of plant density and fruit load on flowering time in days from pruning was found to be non-significant during both year experimentations.

Effect of plant density and fruit load on fruit set

Effect of plant density on fruit set

Data presented in Table 1 revealed that, significantly highest percentage of fruit set were found in spacing 4.0 x 2.5 m (73.20% and 74.07%) which was superior than all others followed by spacing 4.0 x 4.0 m (69.80% and 71.40%).

However, lowest percentage of fruit set were noticed in spacing 3.0 x 3.0 m (68.33% and 69.73%) during both the years of experimentation.

Similarly, on the basis of mean pooled data it is revealed that significantly highest percentage of fruit set were found in spacing 4.0 x 2.5 m (73.59%) which was superior than all others followed by spacing 4.0 x 4.0 m (70.50%). However, lowest percentage of fruit set were noticed in spacing 3.0 x 3.0 m (68.83%).

This might be attributes to fact that, in high density planting plants flowered 48 hours earlier in time when climatic conditions were favorable but as the spacing was increased the flowering also delayed which coincided with the heavy rains that caused flower drop and fruit drop which ultimately resulted in less fruit percentage. The results of present findings are in agreement with the findings of Singh and Sandhu (1984) [26] and Mohamed *et al.* (2010) [17] in custard apple.

Effect of fruit load on fruit set

Data presented in Table 1 revealed that, significantly highest percentage of fruit set were found in the treatment fruit retention 60 per plant (72.56% and 74.33%) which was superior than all others followed by the treatment fruit retention 80 per plant (72.33% and 73.00%), the treatment fruit retention 100 per plant (71.11% and 72.67%) and the treatment fruit retention 40 per plant (69.22% and 70.33%). However, lowest percentage of fruit set were noticed in the treatment no fruit thinning (67.00% and 68.33%) during both the years of experimentation. Meanwhile the treatment fruit retention 60 per plant (72.56% and 74.33%), the treatment fruit retention 80 per plant (72.33% and 73.00%) and the treatment fruit retention 100 per plant (71.11% and 72.67%) were found at par.

Similarly, on the basis of mean pooled data it is revealed that significantly highest percentage of fruit set were found in the treatment fruit retention 60 per plant (73.50%) which was superior than all others followed by the treatment fruit retention 80 per plant (72.59%), the treatment fruit retention 100 per plant (71.33%) and the treatment fruit retention 40 per plant (69.78%). However, lowest percentage of fruit set were noticed in the treatment no fruit thinning (67.67%). Meanwhile the treatment fruit retention 60 per plant (73.50%), the treatment fruit retention 80 per plant (72.59%) and the treatment fruit retention 100 per plant (71.33%) were found at par.

This might be attributes to fact that, in low fruit retention plants flowered earlier in time when climatic conditions were favorable but as the spacing was increased the flowering also delayed which coincided with the heavy rains that caused flower drop and fruit drop which ultimately resulted in less fruit percentage. The results of present findings are in agreement with the findings of Singh and Sandhu (1984) [26] and Mohamed *et al.* (2010) [17] in custard apple.

Effect of plant density and fruit load on total number of fruits per plant

Effect of plant density on total number of fruits per plant

The results regarding number of fruits per plant are presented in Table 2. The data revealed that, number of fruits per plant (79.93 and 80.28) was recorded in the spacing 4.0 m x 4.0 m which was significantly superior and statistically at par with the treatments of spacing 4.0 m x 2.5 m (78.89 and 79.34) and spacing 3.0 m x 3.0 m (78.59 and 79.04) in the years 2019 and 2020 of experimentation.

Similarly pooled mean of two-year data for the highest number of fruits per plant were obtained in the spacing 4 x 4 m (80.26) followed by the spacing 3 x 3 m (79.01) while the lowest number of fruits per plant were obtained in the spacing 4 x 2.5 m (78.62). The number of fruits recorded in the spacing 4 x 2.5 m (78.62) and 3 x 3 m (79.01) are significant and statistically at par with each other in both the year of experimentation. The increase in number of fruits of custard apple because of heavy cropping reduced average fruit size and the percentage of extra-large fruit weighing more than 500 g. This finding is in close conformity with the finding of Chander and Reju (2019) [8, 25] in custard apple.

Effect of fruit load on total number of fruits per plant

The results regarding number of fruits per plant are presented in Table 2. The data revealed that, maximum number of fruits per plant was recorded in treatment of no fruit retention i.e., no thinning (115.68 and 117.77) followed by the treatment fruit retention 100 (100), the treatment fruit retention 80 per plant (80), the treatment fruit retention 60 per plant while the minimum number of fruits per plant was recorded in the treatment fruit retention 40 per plant (40) in the in the years 2019 and 2020 of experimentation respectively.

Similarly, pooled mean of highest number of fruits per plant found in treatment no fruit thinning (116.48) followed by followed by the treatment fruit retention 100 (100), the treatment fruit retention 80 per plant (80), the treatment fruit retention 60 per plant while pooled mean of lowest number of fruits per plant were recorded in the treatment fruit retention 40 per plant (40). The increase in number of graded fruits of custard apple because of heavy cropping reduced average fruit size and the percentage of extra-large fruit weighing more than 500 g. This finding is in close conformity with the finding of Chander and Reju (2019) [8, 25] in custard apple.

From the data presented in Table 2 it revealed that trees which were kept as control (no fruit thinning) gives more number of fruits per plant. It might be due to the fact that there was no thinning of fruits in control. Meland (2009) [16] reported that in apple fruit thinning causes a significant reduction in number of fruit as well as yield per tree.

Effect of interaction

The results regarding number of fruits per plant are presented in Table 2. The data revealed that, maximum number of fruits per plant was recorded in S1T5 i. e. spacing 4 x 4 m with no fruit thinning (119.63 and 121.406.70) followed by S2T5 i.e. spacing 4 x 2.5 m with no fruit thinning (114.33 and 116.70) and S3T5 i.e. spacing 3 x 3 m with no fruit thinning (112.97 and 115.20) treatment no thinning of all spacing during both years of experimentation. However, the lowest number of fruits recorded in all spacing with fruit retention 40 per plant (40 and 40).

Effect of plant density and fruit load on fruit yield per plant

Effect of plant density on fruit yield per plant

The results regarding fruit yield per plant are presented in Table 2. The data revealed that, significantly the highest fruit yield per plant were recorded in the plant spacing 4.0 x 2.5 m (20.67 kg and 21.47 kg) which was superior than all the treatments followed by plant spacing 4.0 x 4.0 m (18.40 kg and 19.27 kg) while lowest fruit yield per plant were recorded in the spacing 3.0 m x 3.0 m (17.13 kg and 18.33 kg) in both the years of experimentation.

Similarly pooled mean of two-year data, significantly the highest fruit yield per plant were recorded in the plant spacing 4.0 x 2.5 m (21.07 kg)which is superior than others followed by plant spacing 4.0 x 4.0 m (18.84 kg) while lowest fruit yield per plant were recorded in the spacing 3.0 m x 3.0 m (17.73 kg). The yield per plant was observed maximum because of optimum balance between the vegetative and reproductive growth of trees and maximum number of fruits increase the yield per plant. In custard apple the flowers and fruits are born on current season growth, a light annual pruning is necessary to encourage new shoots after harvest. High density planting along with pruning also reduces tree crown area and increase number of fruits. The results are in close agreement with the Mohommad *et al.* (2005) and Ghum (2011) [12] in custard apple and Kumar and Rattanpal (2010) [14] in guava, Masalkar and Joshi (2009) [15] and Sheikh and Rao (2002) [23] in pomegranate.

Effect of fruit load on fruit yield per plant

The data presented in Table 2 revealed that significantly highest fruit yield per plant was recorded in treatment of 60 fruit retention per plant (23.00 kg and 23.67 kg) which is superior than all other treatments followed by the treatment of fruit retention 80 per plant (19.88 kg and 20.44 kg) while the lowest fruit yield per plant was recorded in treatment of no fruit retention i.e., no fruit thinning (14.67 kg and 15.89 kg) which was statistically at par with the treatments of fruit retention 40 per plant (15.92 kg and 17.00 kg) in both the years of experimentation.

Similarly pooled mean of two-year data, significantly the highest fruit yield per plant was recorded in treatment of 60 fruit retention per plant (23.00 kg) which is superior than all other treatments followed by the treatment of fruit retention 80 per plant (21.83 kg) while the lowest fruit yield per plant was recorded in treatment of no fruit retention i.e., no fruit thinning (15.89 kg) which was statistically at par with the treatments of fruit retention 40 per plant (17.44 kg).

Reduction in yield with this treatment could be attributed to decrease in number of fruits per tree. Similar findings were also reported by Channa *et al.* (1998) and Casierra *et al.* (2007) [7] in peach. Sdoodee *et al.* (2008) [21] reported that the highest yield was found in high crop load in mangosteen trees.

Effect of interaction

Data presented in Table 2 revealed that, an interaction effect of plant density and fruit load on fruit yield per plant was found to be non-significant during both year experimentations while pooled data was found significant.

The pooled mean of two-year data for the fruit yield per plant was recorded in the spacing 4 x 2.5 m with the treatment of fruit retention 60 per plant (24.17 kg) followed by the spacing 4 x 4 m with the treatment of fruit retention 60 per plant (23.17 kg) and the spacing 3 x 3 m with the treatment of fruit retention 60 per plant (21.67 kg) and statistically at par with each other. However, the lowest fruit yield per plant was recorded in the spacing 3 x 3 m with the treatment n fruit retention i.e., no thinning (14.83 kg).

Effect of plant density and fruit load on fruit yield per ha (q/ha)

Effect of plant density on fruit yield per hectare

The results regarding fruit yield per hectare are presented in Table 2. The data revealed that, significantly the highest fruit yield/ha were recorded in the plant spacing 4.0 x 2.5 m (200.93 q and 203.33 q) which was superior than all the treatments followed by plant spacing 3 x 3 m (182.56 q and 184.27 q) while lowest fruit yield per plant were recorded in the spacing 4 x 4 m (117.37 q and 119.60 q) in both the years of experimentation.

Similarly pooled mean of two-year data, significantly the highest fruit yield/ha were recorded in the plant spacing 4 x 2.5 m (202.13 q) which was superior than all the treatments followed by plant spacing 3 x 3 m (183.42 q) while lowest fruit yield per plant were recorded in the spacing 4 x 4 m (118.48 q).

The yield/ha was observed maximum because of number of plants population are more in high density planting and optimum balance between the vegetative and reproductive growth of trees and maximum number of fruits increase the yield per hectare. In custard apple the flowers and fruits are born on current season growth. High density planting reduces tree crown area and increase number of fruits. The results are in close agreement with the Mohmad *et al.* (2005) and Ghum (2011) [12] in custard apple and Kumar and Rattanpal (2010) [14] in guava, Masalkar and Joshi (2009) [15] and Sheikh and Rao (2002) [23] in pomegranate.

Effect of fruit load on fruit yield per hectare

The data presented in Table 2 revealed that significantly highest fruit yield/ha was recorded in treatment of 60 fruit retention per plant (209.10 q and 211.33 q) which is superior than all other treatments followed by the treatment of fruit retention 80 per plant (180.89 q and 183.56 q) while the lowest fruit yield per plant was recorded in treatment of no fruit retention i.e., no fruit thinning (133.51 q and 134.33 q) in both the years of experimentation.

Similarly pooled mean of two-year data, significantly the highest fruit yield/ha was recorded in treatment of 60 fruit retention per plant (210.22 q) which is superior than all other treatments followed by the treatment of fruit retention 80 per plant (182.22 q) while the lowest fruit yield per plant was recorded in treatment of no fruit retention i.e., no fruit thinning (133.92 q).

Increasing plant population in high density planting as compared to normal spacing the per hectare yield increases. Fruit retention helps for enlarging the fruit size and therefore the yield increases. Similar findings were also reported by Channa *et al.* (1998) and Casierra *et al.* (2007) [7] in peach. Sdoodee *et al.* (2008) [21] reported that the highest yield was found in high crop load in mangosteen trees.

Effect of interaction

Data presented in Table 2 revealed that, an interaction effect of plant density and fruit load on fruit yield/ha was found to be significant during both year experimentations.

The data for the fruit yield/ha was recorded in the spacing 4 x 2.5 m with the treatment of fruit retention 60 per plant (243.33 q and 246.00 q) followed by the spacing 3 x 3 m with the treatment of fruit retention 60 per plant (240.72 q and

242.67 q) which were found at par with each other. Also, the fruit yield/ha recorded in S2T1 i.e., the spacing 4 x 2.5 m with the treatment of fruit retention 100 per plant (200.00 q and 204.00 q), S2T2 (210.00 q and 211.33 q) and S3T2 (201.67 q and 205.33 q) were found at par. However, the lowest fruit yield/ha was recorded in the spacing 4 x 4 m with the treatment no fruit thinning (93.25 q and 94.67 q).

The pooled mean of two-year data for the fruit yield/ha was recorded in the spacing 4 x 2.5 m with the treatment of fruit retention 60 per plant (244.67 q) followed by the spacing 3 x 3 m with the treatment of fruit retention 60 per plant (241.69 q) which were found at par with each other. Also, the fruit yield/ha recorded in S2T1 i.e., the spacing 4 x 2.5 m with the treatment of fruit retention 100 per plant (202.00 q), S2T2 (210.67 q) and S3T2 (203.50 q) were found at par. However, the lowest fruit yield/ha was recorded in the spacing 4 x 4 m with the treatment no fruit thinning (93.96 q).

Increasing plant population in high density planting as compared to normal spacing the per hectare yield increases. Fruit retention helps for enlarging the fruit size and therefore the yield increases. Similar findings were also reported by Channa *et al.* (1998) and Casierra *et al.* (2007) [7] in peach. Sdoodee *et al.* (2008) [21] reported that the highest yield was found in high crop load in mangosteen trees.

Physico-chemical parameters

The observations regarding the effect of planting density and fruit load on physico-chemical quality of custard apple *viz*., fruit weight (g), pulp weight (g) and peel weight (g) are presented in Tables 3.

Effect of plant density and fruit load on fruit weight

The data regarding the physical quality parameters i.e., fruit weight of custard apple was significantly influenced by the spacing and fruit load during both the years (2019 and 2020) of experimentation.

Effect of plant density on fruit weight

Data presented in Table 3 revealed that, highest fruit weight (284.92 g and 288.17 g) was noticed in spacing 4.0 x 2.5 m which was significantly superior and statistically at par with the spacing 4.0 x 4.0 m (281.69 g and 284.27 g) during the year 2019 and 2020. However, significantly lowest fruit weight (266.87 g and 270.00 g) was recorded in the spacing 3.0 x 3.0 m.

Similarly, pooled mean of two-year data for the highest fruit weight (286.84 g) was recorded in the spacing 4.0 x 2.5 m which was significantly superior and statistically at par with the spacing 4.0 x 4.0 m (282.98 g). While pooled mean of two-year data for the lowest fruit weight (268.43 g) was observed in the spacing 3.0 x 3.0 m.

This is might be due to the closer spacing had higher average weight in relation fruits produced by plants subjected to light pruning with closer spacing and fruit retention. The results of present findings are in agreement with the findings of Mohamed *et al.* (2010) [17] and Dahapute *et al.* (2018) [10] in custard apple.

Effect of fruit load on fruit weight

Data presented in Table 3 revealed that, the treatment fruit retention 60 per plant recorded highest fruit weight (310.79 g and 314.34 g) which was significantly superior than rest of all the treatments during the year 2019 and 2020. It was followed by the treatment fruit retention 80 per plant having fruit weight (282.74 g and 286.97 g) and the treatment fruit retention 100 per plant having fruit weight (276.48 g and 278.09 g). However, significantly the lowest fruit weight (249.22 g and 252.89 g) was recorded in the treatment control i.e. no fruit thinning followed by the treatment fruit retention 40 per plant (269.89 g and 271.78 g).

Similarly, the pooled mean of two-year data for the highest fruit weight (312.72 g) was observed in the treatment fruit retention 60 per plant while pooled mean of two-year data for the lowest fruit weight (268.43 g) was recorded in the treatment no fruit thinning.

This is might be due to the fruit retention had higher average weight in relation fruits produced by plants subjected with low fruit retention per tree. The results of present findings are in agreement with the findings of Mohamed *et al.* (2010) [17] and Dahapute *et al.* (2018) [10] in custard apple.

Interaction effect

Data presented in Table 3 revealed that, an interaction effect of plant density and fruit load on fruit weight influenced by spacing and fruit load was found to be significant during both year experimentations. However, the highest fruit weight (324.63 g and 327.67 g) was observed in the interaction of the treatment fruit retention 60 per plant with 4.0 x 2.5 m spacing was statically at par with spacing 4.0 x 4.0 m and the treatment fruit retention 60 per plant (321.07 g and 323.67 g) while the treatment fruit retention 80 per plant (285.78 g and 289.67 g) and fruit retention 100 per plant (277.92 g and 278.33 g) were statically at par in the spacing 4.0 x 2.5 m. Likewise spacing 4.0 x 2.5 m with the treatment fruit retention 80 per plant (289.10 g and 292.91 g) and fruit retention 100 per plant (282.18 g and 283.93 g) were statically at par.

However, the pooled mean of two years, the highest fruit weight (329.79 g) was recorded in the spacing 4 x 2.5 m with the treatment fruit retention 60 per plant (329.79 g) followed by the spacing 4 x 4 m with the treatment fruit retention 60 per plant (319.22 g) and the spacing 3 x 3 m having treatment fruit retention 60 per plant (389.17 g) while in the spacing 4.0 x 2.5 m, the treatment fruit retention 80 per plant (287.73 g) and fruit retention 100 per plant (278.13 g) were statically at par.

Likewise spacing 4.0 x 2.5 m with the treatment fruit retention 80 per plant (289.10 g and 292.91 g) and fruit retention 100 per plant (282.18 g and 283.93 g) were statically at par.

This is might be due to the fruit retention had higher average weight in relation fruits produced by plants subjected with closer spacing and fruit retention. The results of present findings are in agreement with the findings of Mohamed *et al.* (2010) [17] and Dahapute *et al.* (2018) [10] in custard apple.

Effect of plant density on pulp weight

Data presented in Table 3 revealed that, highest pulp weight (153.05 g and 155.48 g) were noticed in spacing 4.0 x 2.5 m which was significantly superior and statistically at par with the spacing 4.0 x 4.0 m (151.18 g and 153.14 g) during the year 2019 and 2020. However, significantly lowest pulp weight (145.58 g and 147.62 g) was recorded in the spacing 3 x 3 m.

Similarly pooled mean of two-year data for the highest pulp weight (154.26 g) were observed in the spacing 4.0 x 2.5 m and statistically at par with the spacing 4.0 x 4.0 m (152.16 g) while pooled mean of two-year data for the lowest pulp weight (123.01 g) were observed in the 3.0 x 3.0 m spacing.

The increase in pulp weight could be attributed to increase in fruit size which resulted in higher proportionate pulp weight and increased marginal stone weight. The present findings are in close conformity with the findings of Casierra *et al.* (2007) [7] in peach.

The increase in pulp weight may also be due to increased fruit weight coupled with induced cell division and assimilate mobilization in the developing berries. This finding is agreement with the findings by Rizk *et al.*, (2011) [20] in grapes.

Effect of fruit load on pulp weight

Data presented in Table 3 revealed that, the treatment fruit retention 60 per plant recorded highest pulp weight (168.25 g and 170.70 g) were noticed in fruit load which was significantly superior than rest of all the treatments during the year 2019 and 2020. It was followed by the treatment fruit retention 80 per plant (150.65 g and 152.60 g) and the treatment fruit retention 100 per plant (147.32 g and 149.42 g) while the treatment fruit retention 100 per plant (147.32 g and 149.42 g) is statistically at par with the treatment fruit retention 40 per plant (147.54 g and 149.70 g). However, significantly lowest pulp weight (135.92 g and 137.96 g) was recorded in the treatment no fruit thinning.

Similarly pooled mean of two-year data for the significantly highest pulp weight (169.67 g) were observed in the treatment fruit retention 60 per plant while the treatment fruit retention 100 per plant (148.37 g) is statistically at par with the treatment fruit retention 40 per plant (148.62 g). However, the pooled mean of two-year data for the lowest pulp weight (136.94 g) was observed in the treatment no fruit thinning.

The increase in pulp weight could be attributed to increase in fruit size which resulted in higher proportionate pulp weight and increased marginal stone weight. The present findings are in close conformity with the findings of Casierra *et al.* (2007) [7] in peach.

The increase in pulp weight may also be due to increased fruit weight coupled with induced cell division and assimilate mobilization in the developing berries. This finding is agreement with the findings by Rizk *et al.*, (2011) [20] in grapes.

Interaction effect

Data presented in Table 3 revealed that, an interaction effect of plant density and fruit load on pulp weight influenced by spacing and fruit load was found to be non-significant during both year experimentations.

Effect of plant density and fruit load on peel weight

Effect of plant density on peel weight

Data presented in Table 3 revealed that, the significantly highest peel weight (123.01 g and 125.63 g) was found in the spacing 3.0 x 3.0 m than rest of all the treatments during the year 2019 and 2020.It was followed by the spacing 4.0 x 4.0 m (121.49 g) and statistically at par with the spacing 3.0 x 3.0 m (123.01 g) in the year 2019.However, the lowest peel weight (117.41 g and 119.49 g) was noticed in spacing 4.0 x 2.5 m which was significantly superior.

Similarly, pooled mean of two-year data for the significantly highest peel weight (124.32 g) were observed in the spacing 3.0 x 3.0 m while pooled mean of two-year data for the lowest peel weight (118.45 g) were observed in the spacing 4.0 x 2.5 m.

The increase in peel weight could be attributed to increase in fruit size which resulted in higher proportionate of peel weight and increased marginal stone weight. The present findings are in close conformity with the findings of Casierra *et al.* (2007) [7] in peach.

This might be due to the high density and pruning may increases absorption of water, mobilization of minerals in pruned area. These findings are in accordance with the results obtained by Bruno and Evelyn (2001) [6] in custard apple, Adhikari and Kandel (2015) [2] in guava, Singh and Bal (2008) in Ber tree.

Effect of fruit load on peel weight

Data presented in Table 3 revealed that, the treatment fruit retention 60 per plant recorded highest peel weight (135.22 g and 136.95 g) were noticed in fruit load which was significantly superior than rest of all the treatments during the year 2019 and 2020. It was followed by the treatment fruit retention 80 per plant (121.07 g and 123.07 g) and the treatment fruit retention 80 per plant (121.07 g and 123.07 g), 100 per plant (121.07 g and 123.07 g) and the treatment fruit retention 40 per plant are statistically at par. However, significantly lowest peel weight (109.24 g and 112.41 g) was recorded in the treatment no fruit thinning.

Similarly pooled mean of two-year data for the highest peel weight (136.08 g) were observed in the treatment fruit retention 60 per plant while pooled mean of two-year data for the lowest peel weight (110.82 g) were observed in the treatment no fruit thinning.

The increase in peel weight because of more cell division by hormones developed activities, thereby increasing the cell density per unit volume. This finding is in close conformity with the finding of Bhat *et al.*, (2012) [5] in grape.

Interaction effect

Data presented in Table 3 revealed that, an interaction effect of plant density and fruit load on peel weight influenced by spacing and fruit load was found to be non-significant during first (2019) and significant during second (2020) year of experimentations. However, the highest peel weight (129.17 g and 130.47 g) was observed in the interaction of the treatment fruit retention 60 per plant with 4.0 x 2.5 m spacing.

Table 1: Effect of plant density and fruit load on number of flowers per shoot, flowering time (in day from pruning) and fruit set (%)

Treatments	Number of flowers per shoot			Flowering time (in days from pruning)			Fruit set (%)		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
	Spacing								
S1: 4.0 x 4.0 m	16.91	17.12	17.02	33.00	34.07	33.53	69.80	71.40	70.50
S2: 4.0 x 2.5 m	16.00	16.26	16.13	32.40	33.53	32.97	73.20	74.07	73.59
S3 : 3.0 x 3.0 m	14.41	14.59	14.50	34.60	35.20	34.90	68.33	69.73	68.83
F-test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.

SE(m)+	0.07	0.07	0.07	0.435	0.382	0.368	0.45	0.43	0.39
CD 5%	0.20	0.20	0.19	1.267	1.112	1.072	1.311	1.24	1.13
	Fruit Load								
T1 : Fruit retention 100/ plant	15.40	15.57	15.48	33.22	34.11	33.67	71.11	72.67	71.33
T2 : Fruit retention 80/ plant	16.56	16.79	16.67	32.11	33.33	32.72	72.33	73.00	72.59
T3 : Fruit retention 60/ plant	17.94	18.25	18.10	32.00	32.89	32.44	72.56	74.33	73.50
T4 : Fruit retention 40/ plant	15.33	15.50	15.41	34.00	34.88	34.44	69.22	70.33	69.78
T5 : No fruit thinning	13.63	13.84	13.74	35.33	36.11	35.72	67.00	68.33	67.67
F-test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SE(m)+	0.09	0.09	0.08	0.562	0.493	0.475	0.58	0.55	0.50
CD 5%	0.26	0.25	0.24	1.635	1.435	1.384	1.69	1.60	1.46
	Interaction (S X T)								
S1T1	16.60	16.84	16.72						
S1T2	17.76	18.02	17.89						
S1T3	19.80	19.97	19.88						
S1T4	15.92	16.12	16.02						
S1T5	14.46	14.66	14.56						
S2T1	15.59	15.80	15.70						
S2T2	16.83	17.11	16.97						
S2T3	18.32	18.74	18.53						
S2T4	15.54	15.67	15.61						
S2T5	13.70	13.98	13.84						
S3T1	14.00	14.06	14.03						
S3T2	15.08	15.23	15.15						
S3T3	15.70	16.06	15.88						
S3T4	14.54	14.70	14.62						
S3T5	12.73	12.89	12.81						
F-test	Sig.	Sig.	Sig.	NS	NS	NS	NS	NS	NS
SE(m)+	0.16	0.15	0.15	0.973	0.854	0.823	10.01	0.95	0.87
CD 5%	0.45	0.44	0.42	--	--	--	--	--	--

Table 2: Effect of plant density and fruit load on total number of fruits per plant, fruit yield per plant (Kg) and fruit yield per ha (q)

Treatments	Total number of fruits per plant			Fruit yield per plant (Kg)			Fruit yield per ha (q)		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
	Spacing								
S1: 4.0 x 4.0 m	79.93	80.28	80.26	18.40	19.27	18.84	117.37	119.60	118.48
S2: 4.0 x 2.5 m	78.89	79.34	78.62	20.67	21.47	21.07	200.93	203.33	202.13
S3 : 3.0 x 3.0 m	78.59	79.04	79.01	17.13	18.33	17.73	182.56	184.27	183.42
F-test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SE(m)+	0.35	0.35	0.34	0.54	0.33	0.22	2.99	2.35	2.61
CD 5%	1.01	1.02	0.99	1.56	0.98	0.66	8.70	6.84	7.60
	Fruit Load								
T1 : Fruit retention 100/ plant	100.00	100.00	100.00	17.22	18.11	18.94	162.30	164.67	163.48
T2 : Fruit retention 80/ plant	80.00	80.00	80.00	19.88	20.44	21.83	180.89	183.56	182.22
T3 : Fruit retention 60/ plant	60.00	60.00	60.00	23.00	23.67	23.00	209.10	211.33	210.22
T4 : Fruit retention 40/ plant	40.00	40.00	40.00	15.92	17.00	17.44	148.98	151.44	150.21
T5 : No fruit thinning	115.68	117.77	116.48	14.67	15.89	15.89	133.51	134.33	133.92
F-test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SE(m)+	0.45	0.45	0.44	0.69	0.43	0.29	3.86	3.03	3.37
CD 5%	1.31	1.32	1.28	2.02	1.27	0.85	11.23	8.82	9.82
	Interaction (S X T)								
S1T1	100.00	100.00	100.00				112.83	115.00	113.92
S1T2	80.00	80.00	80.00				131.00	134.00	132.50
S1T3	60.00	60.00	60.00				143.25	145.33	144.29
S1T4	40.00	40.00	40.00				106.50	109.00	107.75
S1T5	119.63	121.40	121.28				93.25	94.67	93.96
S2T1	100.00	100.00	100.00				200.00	204.00	202.00
S2T2	80.00	80.00	80.00				210.00	211.33	210.67
S2T3	60.00	60.00	60.00				243.33	246.00	244.67
S2T4	40.00	40.00	40.00				188.50	191.67	190.08
S2T5	114.33	116.70	113.12				162.83	163.67	163.25
S3T1	100.00	100.00	100.00				174.06	175.00	174.53
S3T2	80.00	80.00	80.00				201.67	205.33	203.50
S3T3	60.00	60.00	60.00				240.72	242.67	241.69
S3T4	40.00	40.00	40.00				151.95	153.67	152.81
S3T5	112.97	115.20	115.05				144.43	144.67	144.55

F-test	Sig.	Sig.	Sig.	NS.	NS.	NS	Sig.	Sig.	Sig.
SE(m)+	0.78	0.78	0.76	1.20	0.75	0.823	6.68	5.25	5.84
CD 5%	2.26	2.28	2.22	--	---	--	19.45	15.28	17.00

Table 3: Effect of plant density and fruit load on fruit weight (g), pulp weight (g) and peel weight (g)

Treatments	Fruit weight (g)			Pulp weight (g)			Peel weight (g)		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
	Spacing								
S1: 4.0 x 4.0 m	281.69	284.27	281.69	151.18	153.14	152.16	121.49	123.20	122.35
S2: 4.0 x 2.5 m	284.92	288.17	284.92	153.05	155.48	154.26	117.41	119.49	118.45
S3 : 3.0 x 3.0 m	266.87	270.00	266.87	145.58	147.62	146.60	123.01	125.63	124.32
F-test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SE(m)+	1.51	1.51	1.51	0.82	0.79	0.80	0.65	0.57	0.60
CD 5%	4.40	4.39	4.40	2.45	2.36	2.38	1.90	1.67	1.74
	Fruit Load								
T1 : Fruit retention 100/ plant	276.48	278.09	276.48	147.32	149.42	148.37	118.39	119.97	119.18
T2 : Fruit retention 80/ plant	282.74	286.97	282.74	150.65	152.60	151.63	121.07	123.07	122.07
T3 : Fruit retention 60/ plant	310.79	314.34	310.79	168.25	170.70	169.47	135.22	136.95	136.08
T4 : Fruit retention 40/ plant	269.89	271.78	269.89	147.54	149.70	148.62	119.28	121.47	120.37
T5 : No fruit thinning	249.22	252.89	249.22	135.92	137.96	136.94	109.24	112.41	110.82
F-test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SE(m)+	1.95	1.95	1.95	1.05	1.02	1.03	0.840	0.741	0.773
CD 5%	5.69	5.67	5.69	3.07	2.97	3.01	2.445	2.156	2.250
	Interaction (S X T)								
S1T1	277.92	278.33	278.13					115.00	
S1T2	285.78	289.67	287.73					134.00	
S1T3	321.07	323.67	319.22					145.33	
S1T4	275.67	278.0	276.83					109.00	
S1T5	248.00	251.67	249.83					94.67	
S2T1	282.18	283.93	283.06					204.00	
S2T2	289.10	292.91	291.00					211.33	
S2T3	324.63	327.67	329.79					246.00	
S2T4	274.00	275.33	274.67					191.67	
S2T5	254.67	261.00	255.67					163.67	
S3T1	269.33	272.00	270.67					175.00	
S3T2	272.33	278.33	275.83					205.33	
S3T3	286.67	291.67	289.17					242.67	
S3T4	260.0	262.00	261.00					153.67	
S3T5	245.00	246.00	245.50					144.67	
F-test	Sig.	Sig.	Sig.	NS	NS	NS	NS	Sig.	NS
SE(m)+	3.38	3.37	3.02	1.83	1.77	1.79	1.454	1.283	1.339
CD 5%	9.85	9.82	8.79	NS	NS	NS	--	3.735	---

Conclusions

1. On the basis of results obtained in the present experiment entitled "Effect of planting density and fruit load on fruit yield and quality of custard apple" it may be concluded that, plant growth was increased in linear order with planting density and fruit load. The treatment combination of 4.0 x 4.0 m with 60 fruit retention per plant has found most effective in growth parameters. Similarly, fruit yield and yield contributing parameters *viz*., number of fruits per plant, average weight of fruit and graded fruit yield were found superior in treatment combination of 4.0 x 2.5 m spacing with 60 fruit load per plant.
2. Better fruit quality in respect of fruit size, pulp weight and peel weight were noted when spacing 4.0 x 2.5 m with 60 fruit retention per plant. Positive and significant correlation was observed between fruit yield and fruit load.
3. Based on overall performance in terms of plant growth, yield, fruit quality and B:C ratio, it can be concluded that, under high density planting (4 x 2.5 m) keeping 60 fruits per plant appears to be best for young bearing custard apple orchard.

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