International Journal of Environment and Climate Change

Volume 14, Issue 1, Page 443-452, 2024; Article no.IJECC.111841
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Influence of Crop Geometry, Fruit Thinning and Nutrient Management on Yield and Yield -related Attributes of Watermelon (*Citrullus lanatus* Thumb.)

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Authors' contributions

This work was carried out in collaboration among all authors. Authors PKB and BD did the conceptualization and designing of the research work. Authors UK and PK did the execution of field/lab experiments and data collection. Authors BG, AS and SG did the analysis of data and interpretation. Authors JH, BD, KH and BH did the preparation of manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2024/v14i13854

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/111841

Original Research Article

Received: 09/11/2023
Accepted: 11/01/2024
Published: 16/01/2024

ABSTRACT

The present experiment was carried out during 2020-21 and 2021-22 in Jorhat, Assam with the objective to optimize the planting density for maximum yield and yield related attributes. The experiment was laid out in factorial randomized block Design with 3 factors *viz.* spacing, fruit

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thinning and INM (Integrated nutrient management) with three replications and the data of individual years were subjected to pooled analysis. The spacing levels were D_1 (2.5m x 2m), D_2 (1.5m x 1m) and D_3 (1mx 1m) where F_1 (no thinning), F_2 (Thinning up-to 1 fruits /primary vine) and F_3 (Thinning up-to2 fruits/primary vine) were the fruit thinning levels. A total of 4 INM treatments were given *i.e.* N_1 (100% RDF), N_2 (50% RDF + 50% RDN through FYM), N_3 (50% RDF + 50% RDN through vermicompost) and N_4 (50% RDF + 25% RDN through vermicompost + 25% RDN through FYM). The treatments significantly influenced the various parameters except a few. The experiment's findings showed that thinning the fruit and increasing the spacing between them had a favorable effect on the watermelon's growth and yield-related characteristics. Additionally, integrated nutrient management and fruit thinning at level F2 enhanced the watermelon's growth, yield, and quality metrics. Among the levels, N3 (50% RDF + 50% RDN through vemicompost was found to be the best.

Keywords: Crop geometry; fruit thinning; nutrient management; watermelon; yield attributes.

1. INTRODUCTION

The watermelon *Citrullus lanatus* (Thunb.), is a member of the cucurbitaceae family, which is divided into several genera. The crop is said to have originated in Africa and spread around the world [1]. It is one of the significant cucurbits that is extensively grown and eaten as fruit by a sizable portion of the global populace. Its inexpensive cost, sweet flavour, and juicy pulp are the main reasons for its acceptance. Watermelon fruits are rich in antioxidants and have high levels of lycopene and carotenoids. For a good production, the majority of the cultivars grow long, prostrate vines that need a lot of horizontal area. The crop absorbs a significant amount of soil moisture to produce the luscious fruits, which are primarily consumed as pleasant and refreshing sources of water [2]. [3] discovered that the ideal temperature range for watermelon production is between 18° and 35°C. With a total production of 79,276,300 tonnes and a productivity of 42.88 t/ha, China leads the world. The other top nations are Uzbekistan, Brazil, Turkey, and Iran. The crop is cultivated under irrigation or with rain feeding during the summer and Rabi seasons. Uttar Pradesh, Maharashtra, Karnataka, Tamil Nadu, Punjab, Rajasthan, Madhya Pradesh, Gujarat, and Andhra Pradesh are the states that cultivate the most watermelon.

Watermelon is becoming more and more popular among farmers in Assam as a reliable source of revenue, drawing them to cultivate the fruit. Consumers are getting increasingly selective about juicy fruits, particularly in the summer. Farmers in the North Bank Plains, Central Brahmaputra Valley Zone, and Lower Brahmaputra Valley Zone mostly raise the crops as rain-fed agriculture.

One of the most crucial elements that have a significant impact on crop productivity is crop geometry. While space, sunlight, and nutrients may be underutilised at wider spacings, these resources become insufficient at closer spacings. Narrower spacing also hinders different intercultural processes. Crop geometry also affects the growth and productivity of individual plants as well as the crop stand per unit area. Because it facilitates the efficient use of resources by plants and ensures that both above-ground and underground plant components develop properly, appropriate spacing increases crop output. One of the key crop management strategies used in many crops to lower the fruit load is fruit thinning. Fruit thinning can be achieved by hand-picking off specific blooms or fruit lets, by using a machine, by using a chemical, or by combining various techniques. Fruit thinning's primary goal is to efficiently preserve the equilibrium between vegetative growth and fruit production, or reproductive plant components [4]. One of the main substitute sources of nutrients is organic manures. In addition to providing significant macro and micronutrients, organic manures enrich soil with organic matter. According to [5], integrated nutrient management (INM) aids in preventing micronutrient deficiencies as well as restoring and maintaining crop output. Crop development and output are consistently supported by an appropriate ratio of inorganic fertilisers to organic manures [6]. The two main sources of organic manure in India are vermicompost and FYM. They also enhance the physico-chemical qualities of soil, promote microbial activity, and provide vital nutrients for plants. The goal of the current study is to optimise planting density for optimum yield and yield-related qualities while keeping in mind the aforementioned facts.

2. MATERIALS AND METHODS

2.1 Experimenral Details

The current study was conducted in the farmer's field in Nahat Chapani village, Teok, in the district of Jorhat, Assam for two consecutive years in 2020–21 and 2021–22, focused on influence of crop geometry, fruit thinning, and nutrient management in yield and yield related attributes of watermelon (*Citrullus lanatus* Thunb.). Three factors—fruit thinning; spacing, and INM—were included in the factorial randomised block design experiment. There were three replications of each element, and a pooled analysis was performed on the data from each year. The fruit thinning levels were F1 (no thinning), F2 (thinning up to 1 fruit /primary vine), and F3 (thinning up to 2 fruits /primary vine). The spacing levels were D1 (2.5 m × 2 m), D2 (1.5 m x 1 m), and D3 (1 m x 1 m).There were four different INM treatments administered: N1 (100% RDF), N2 (50% RDF + 50% RDN through FYM), N3 (50% RDF + 50% RDN through vermicompost), and N4 (50% RDF + 25% RDN through vermicompost + 25% RDN through FYM). The recommended dosage of fertilizers is 60 kg of K2O, 40 kg of N, and 40 kg of P2O5 per hectare. A total of 36 treatment combinations are available.

2.2 Land Preparation and Planting

Ploughing was done with the help of power tiller in last week of January to loosen the soil and left for few days exposed to bright sunshine. After one week, soil was harrowed twice to bring it to fine tilth followed by levelling. During the fourth week of February every year, once the beds had been prepared and mulched, seeds were sown, with holes made according to spacing. Before planting, the seeds were soaked in plain water for the entire night. One seed was planted in each hole. Numerous cultural practices like as irrigation and weeding, were implemented in accordance with recommendations. Thirty millimetre thick layers of black polythene mulch were used to cover the entire experimental area. The necessary steps were taken to protect the plants. Saraswati was the variety chosen for the trial. It is a Know You Seeds India Pvt. Ltd. hybrid that matures quickly and yields a lot. The fruit has a crisp, deep crimson pulp and weighs an average of 2.50–3.00 kg. In addition to being extremely nutrient-dense, the crop has excellent yields. Saraswati is a watermelon hybrid that has a very appealing taste and appearance.

3. PARAMETERS UNDER STUDY

For the purpose of recording the observations, five randomly chosen and marked plants per treatment were used in each replication. Three fruits were chosen at random from the previously tagged plants for each fruit character in order to collect different records. After then, each parameter's average value was determined.

The total quantity of fruits gathered from each of the five tagged plants was used to compute the number of fruits per plant, and the average was given in numerical form. An electronic balance was used to record the weight of each fruit and expressed in kilograms. On the other hand, the length of the fruit (measured in centimetres) was reported from the stem end to the calyx end. In a similar manner, the middle of each fruit was used to estimate its diameter in centimetres. A water displacement method was used to calculate the volume of fruit (cc). The amount of water displaced from the bucket used in the displacement method was measured using a measuring cylinder. The cc symbol for volume was used. The yield per plant, stated in kilograms, was calculated by adding the total number of fruits produced by a single plant to its average fruit weight. The yield per hectare was represented in tonnes and was computed by multiplying the yield per plant by the number of plants per hectare for each treatment.

4. RESULTS AND DISCUSSION

4.1 Yield and Yield Related Attributes

4.1.1 Fruits per plant

The effect of spacing, fruit thinning and nutrient management on fruits per plant is represented in Table 1.a and their interaction effects in Table 1.b.A linear and significant increase in fruits per plant was observed with increasing spacing. D_1 recorded the highest (3.93) number of fruits per plant, which was at par with D_2. The lowest (3.78) was recorded in D_3. This might be due to higher fruit setting and fruit retention under wider spacing [7]. Opined that vine length, leaf area and stem diameter are affected by carbohydrate production through photosynthesis and translocation of hormones which influence the formation of fruits and ultimate the yield.

Present findings are in conformity with the results reported by [8 and 9] in hybrid cucumber; [10] in watermelon.

Fruit thinning and nutrient management also influenced fruit production significantly. In the case of fruit thinning, the maximum (4.78) number of fruits per plant was produced by plants without fruit thinning (F_1), while F_2 recorded the minimum of 2.96 fruits per plant. More availability of photosynthesis in plants with less fruit load because of more leaves per fruit may be the probable cause for better fruit retention and ultimately producing more fruits per plant. Present findings are supported by the reports of [11] in watermelon.

Combined application of organic manures and fertilizers helped in increase of fruit production. N_3resulted in production of the highest (4.21) number of fruitsperplantandtheleastof3.52fruits per plant were inN_1.This might be because of the fact that more vine length and number of primary branches maximized the fruiting buds and ultimately number of fruits per plant increased. The results are in line with the findings of [12] and [13] in watermelon[14]. Also reported similar findings in cucumber and opined that availability of micronutrients and vitamins from organic manures coupled with quick release of nutrients by fertilizers results in higher fruit production.

The interaction of the factors also had a significant influence on the number of fruits per plant. Treatment T3 (D1F1N3) recorded maximum (5.28) fruits per plant as compared to the minimum (2.60) by T29 (D3F2N1).Treatment combinations T4 (D1F1N4), T15 (D2F1N3) and T27 (D3F1N3) with 4.99, 5.16 and 5.08 fruits per plant respectively were at par with the highest. Significance in the interaction effect might be the result of complementary effect of spacing, fruit thinning and nutrient management which recorded significant effects individually.

4.1.2 Fruit length (cm)

Fruit length as affected by spacing, fruit thinning and nutrient management is represented in Table 1.a. An inference could be drawn from the table that among the planting distances, D1 had the longest (25.12 cm) fruit length and in fruit thinning, F2 produced longest fruits of 28.45 cm. Again, among the nutrition levels, N3 resulted in the maximum fruit length of 26.13 cm and the minimum fruit length (23.44 cm) was exhibited by N1. The significant increase in fruit length due to fruit thinning and in wider spacing may be because of better crop stand resulting more availability of photo-assimilates for fruit growth. Increased fruit length recorded with INM may be because of the synergistic interaction of fertilizers and organic manures. Organic manure improves the soil condition and plant health by addition of organic matter to soil and producing plant growth hormones that are involved in cell division and elongation. According to [15] increased availability of carbohydrates during cell division and expansion phase helps in fruit size increase. The results are in conformity with the findings of [16] in cucumber; [17] in pointed gourd and [18] in muskmelon.

Data in Table 1.b shows that the combined effect of the factors was significant. Among the interactions, D1F2N3 (T7) exhibited the longest (29.87 cm) fruit while the shortest of 19.47 cm in D3F1N1 (T25). Complementary effect of spacing, fruit thinning and nutrient management in small magnitude which amplified in combination might have resulted in the significant interaction effect.

4.1.3 Fruit diameter (cm)

Fruit diameter was significantly affected by spacing, fruit thinning, nutrient management and their interactions (Table 1.a and Table 1.b).

Fruit diameter increased linearly with decrease in plant population, the highest being 20.60 cm in D1, while the closest spacing (D3) recorded lowest (20.18) fruit diameter. The present findings are in consonance with the reports of [19] in watermelon. Better crop stands resulting more availability of photo assimilate for fruit growth in wider spacing may attributed to increased fruit diameter. Fruit thinning resulted in an increment of fruit diameter. F2 documented the highest diameter of 22.99 cm. This might have occurred due to the supply of more nutrients to fruits in plants where fruit thinning was done. Further, higher and faster transport of photo-assimilates to the developing fruits might also contribute to the results [20].

Among the nutrient management levels, N3 was found to record the maximum fruit diameter of 21.33 cm and the minimum was 19.49 cm recorded in N1.Increased fruit length recorded with INM may be because of the synergistic interaction of fertilizers and organic manures. Organic manure improves the soil condition and plant health by addition of organic matter to soil and producing plant growth hormones that are involved in cell division and elongation. The results are in consonance with the findings of [21] and [18] in muskmelon. Treatment T7 (D1F2N3) recorded the highest fruit diameter of 24.09 cm which was at par with T8 (23.41), T19 (23.84) and T31 (23.68). The lowest fruit diameter of 16.80 cm was recorded by T25 (D3F1N1). Significant effects of all the factors might have resulted in the significant difference in interaction.

4.1.4 Fruit volume (cc)

The influence of spacing, fruit thinning and nutrient management on fruit volume is represented in Table 1.a. significant variation in the fruit volume was evident from the data. Higher fruit volume was documented in wider spacing; the highest of 2737.44 cc being in D1 and the least of 2633.10cc in D3. Analogous findings were also viewed by [1] in watermelon and [22] in golden melon.

Table 1.a. Number of fruits per plant, fruit length, fruit diameter & fruit volume as influenced by spacing, fruit thinning and nutrient management

	Fruits per plant	Fruit length (cm)	Fruit diameter (cm)	Fruit volume (cc)
D_1	3.93	25.12	20.60	2737.44
D_2	3.85	24.85	20.38	2688.21
D_3	3.78	24.53	20.18	2633.10
S.Em.(±)	0.03	0.06	0.08	15.92
CD(0.05)	0.09	0.17	0.21	44.90
F_1	4.78	21.23	17.87	2078.59
F_2	2.96	28.45	22.99	3260.03
F_3	3.83	24.82	20.31	2720.12
S.Em.(±)	0.03	0.06	0.08	15.92
CD(0.05)	0.09	0.17	0.21	44.90
N_1	3.52	23.44	19.49	2471.85
N_2	3.74	24.48	20.06	2621.69
N_3	4.21	26.13	21.33	2895.58
N_4	3.95	25.29	20.66	2755.88
S.Em.(±)	0.04	0.07	0.09	18.38
CD(0.05)	0.11	0.20	0.25	51.84

Table 1.b. Number of fruits per plant, fruit length fruit, fruit diameter & fruit volume as influencedby interaction of spacing, fruit thinning and nutrient management

Treatment	Fruits per plant	Fruit length (cm)	Fruit diameter (cm)	Fruit volume(cc)
T_1: $D_1F_1N_1$	4.53	19.95	17.11	1896.72
T_2: $D_1F_1N_2$	4.70	21.29	17.78	2069.28
T_3: $D_1F_1N_3$	5.28	22.81	19.08	2371.27
T_4: $D_1F_1N_4$	4.99	21.98	18.39	2198.39
T_5: $D_1F_2N_1$	2.74	27.64	22.30	3075.38
T_6: $D_1F_2N_2$	2.91	28.39	22.94	3223.55
T_7: $D_1F_2N_3$	3.34	29.87	24.09	3530.22
T_8: $D_1F_2N_4$	3.11	28.85	23.41	3391.78
T_9: $D_1F_3N_1$	3.57	23.54	19.59	2594.54
T10:D1F3N2	3.80	24.71	20.16	2719.14
T11:D1F3N3	4.23	26.68	21.61	2961.73
T12:D1F3N4	4.01	25.76	20.76	2817.31
T13:D2F1N1	4.42	19.64	16.96	1839.65
T14:D2F1N2	4.67	21.07	17.45	2015.02
T15:D2F1N3	5.16	22.50	18.83	2295.23
T16:D2F1N4	4.83	21.77	18.28	2176.28
T17:D2F2N1	2.69	27.40	22.15	3056.23
T18:D2F2N2	2.85	28.25	22.75	3178.60

Treatment	Fruits per plant	Fruit length (cm)	Fruit diameter (cm)	Fruit volume(cc)
T19:D2F2N3	3.27	29.48	23.84	3473.41
T20:D2F2N4	3.03	28.68	23.24	3342.76
T21:D2F3N1	3.52	23.28	19.42	2529.54
T22:D2F3N2	3.68	24.22	19.93	2680.58
T23:D2F3N3	4.20	26.47	21.26	2898.68
T24:D2F3N4	3.92	25.42	20.47	2772.53
T25:D3F1N1	4.27	19.47	16.80	1787.96
T26:D3F1N2	4.59	20.52	17.32	1935.04
T27:D3F1N3	5.08	22.24	18.47	2250.93
T28:D3F1N4	4.80	21.52	17.94	2107.36
T29:D3F2N1	2.60	27.08	21.85	3026.85
T30:D3F2N2	2.82	28.12	22.53	3142.60
T31:D3F2N3	3.19	29.14	23.68	3422.09
T32:D3F2N4	2.98	28.55	23.11	3256.90
T33:D3F3N1	3.39	22.92	19.27	2439.77
T34:D3F3N2	3.63	23.78	19.71	2631.40
T35:D3F3N3	4.13	25.98	21.11	2856.70
T36:D3F3N4	3.86	25.06	20.38	2739.59
S.Em.(±)	0.11	0.21	0.26	55.15
CD(0.05)	0.32	0.59	0.74	155.53

In case of fruit thinning F2 recorded the highest (3260.03 cc) volume of fruits. [23] also reported the production of smaller watermelon fruits due to fruit thinning. As the fruit length and diameter increased significantly in wider spacing and due to fruit thinning, the fruit volume also differed significantly. The result clarifies the significant differences in the effect of nutrient management on fruit volume. Incorporation of organic sources of nutrients led to an increase in fruit volume. N3 recorded the maximum (2895.58) fruit volume, while, the minimum of 2471.85 cc recorded in N1. The increase in length and diameter of fruits is attributed towards the significant increment in fruit volume with INM. Similar observations were reported by [24] in watermelon.

The Table 1.b, showed a significant interaction effect. T7 (D1F2N3) recorded the highest (3530.22) fruit volume and at the same time T8 (3391.78), T19 (3473.41) and T31 (3422.09) were having volumes at par with T7. Contrary to it, T25 (D3F1N1) recorded the least fruit volume of 1787.96 cc. significant differences recorded by all the factors might have resulted in significant variations in interactions.

4.1.5 Yield per plant (kg)

Yield per plant as influenced by spacing, fruit thinning, nutrient management and interaction is documented in Table 2.a and Table 2.b. The data revealed that wider spacing resulted in higher yield per plant as compared to the closer spacing. The highest (8.87) yield per plant was recorded in D1 and the least (8.14) in D3. [25] Also viewed analogous findings. This may be due to the production of a greater number of fruits per plant in wider spacing which were having more weight too. Among the fruit thinning levels, F3 recorded the maximum of 8.81 kg yield per plant, being at par with F2 recording 8.67 kg fruits per plant. Present findings are corroborated with the reports of [11] in watermelon. This may be attributed to higher average fruit weight in plants where fruits thinning were done.

In the case of nutrient management, 10.23 kg was the highest yield per plant documented in N3, while 6.87 kg was the lowest yield in N1. Integration of nutrient sources significantly increased the yield per plant as compared to the inorganic nutrient application. This may be attributed to the fact that individual fruit weight and number of fruits per plant was more with INM of crop. Application of organic manures add ample amount of organic matter to the soil which creates preferred microclimatic condition for crop growth inducing better crop stand at reproductive stage resulting more yield per plant. The results are in conformity with the findings of [13] in watermelon; [21] and [18] in muskmelon.

Significant effect of interaction was also recorded. Among all the interaction D1F3N3 (T11) recorded the highest (10.87) yield per plant and the least of 5.91 kg per plant was found in D3F1N1 (T25). This may be due to the fact that all components of interaction had a significant impact on yield per plant.

Table 2.a. Yield per plant and yield per hectare as influenced by spacing, fruit thinning and nutrient management

Treatment	Yield per plant (kg)	Yield per hectare(t)
D_1	8.87	17.74
D_2	8.50	56.69
D_3	8.14	81.42
S.Em.(±)	0.07	0.54
CD(0.05)	0.20	1.53
F_1	8.04	49.00
F_2	8.67	53.02
F_3	8.81	53.83
S.Em.(±)	0.07	0.54
CD(0.05)	0.20	1.53
N_1	6.87	41.86
N_2	7.95	48.61
N_3	10.23	62.55
N_4	8.97	54.78
S.Em.(±)	0.08	0.63
CD(0.05)	0.23	1.77

Table 2.b. Yield per plant and yield per hectare as influenced by interaction of spacing, fruit thinning and nutrient management

Treatment	Yield per plant (kg)	Yield per hectare(t)
T_1: $D_1F_1N_1$	4.53	19.95
T_2: $D_1F_1N_2$	4.70	21.29
T_3: $D_1F_1N_3$	5.28	22.81
T_4: $D_1F_1N_4$	4.99	21.98
T_5: $D_1F_2N_1$	2.74	27.64
T_6: $D_1F_2N_2$	2.91	28.39
T_7: $D_1F_2N_3$	3.34	29.87
T_8: $D_1F_2N_4$	3.11	28.85
T_9: $D_1F_3N_1$	3.57	23.54
T10:D1F3N2	3.80	24.71
T11:D1F3N3	4.23	26.68
T12:D1F3N4	4.01	25.76
T13:D2F1N1	4.42	19.64
T14:D2F1N2	4.67	21.07
T15:D2F1N3	5.16	22.50
T16:D2F1N4	4.83	21.77
T17:D2F2N1	2.69	27.40
T18:D2F2N2	2.85	28.25
T19:D2F2N3	3.27	29.48
T20:D2F2N4	3.03	28.68
T21:D2F3N1	3.52	23.28
T22:D2F3N2	3.68	24.22
T23:D2F3N3	4.20	26.47
T24:D2F3N4	3.92	25.42
T25:D3F1N1	4.27	19.47

Treatment	Yield per plant (kg)	Yield per hectare(t)
T26:D3F1N2	4.59	20.52
T27:D3F1N3	5.08	22.24
T28:D3F1N4	4.80	21.52
T29:D3F2N1	2.60	27.08
T30:D3F2N2	2.82	28.12
T31:D3F2N3	3.19	29.14
T32:D3F2N4	2.98	28.55
T33:D3F3N1	3.39	22.92
T34:D3F3N2	3.63	23.78
T35:D3F3N3	4.13	25.98
T36:D3F3N4	3.86	25.06
S.Em.(±)	0.11	0.21
CD(0.05)	0.32	0.59

4.1.6 Yield per hectare (t)

Table 2.a represents the influence of spacing, fruit thinning and nutrient management on yield per hectare and the interaction effect is documented in Table 2.b. In case of spacing, D3 recorded the highest yield of 81.42 tons per hectare and the lowest yield of 17.74 t/ha was found in D1. This may be attributed to higher plant population in closer spacing which compensated the lower values of average fruit weight in wider spacing. Although the closer spacing recorded lower mean fruit weight, more plants per unit area provided gains in overall productivity. Fruit thinning resulted in a significant increment in yield per hectare. F3 documented the highest yield of 53.83 t/ha and was at par with F2 yielding 53.02 t/ha, while the least yield of 49.00 t/ha was recorded in F1. This may be attributed to the significant increase in yield per plant recorded due to fruit thinning. [26] And [11] also viewed analogous findings in watermelon.

Among the nutrient managements, N3 recorded the highest yield of 62.55 t/ha followed by N4 with 54.78 t/ha and N1 recorded the minimum yield of 41.86 t/ha. The significant increase in yield per hectare may be because of the fact that the highest per plant yield also followed the same trend. Similar findings were reported by [27] in watermelon; [28] in melon. For most species closer spacing usually raises the biomass productivity. But after a certain limit, productivity may remain equal or decrease [29]. Observing the interactions, it could be inferred that treatment T35 (D3F3N3) recorded the highest yield per hectare (100.52 t) and the least (13.24 t) was exhibited by T1 (D1F1N1). The yield of 98.17 t/ha (T31) and 95.11 t/ha (T27) were at par 84 with the highest yield. As all the factors affected the yield significantly, their combinations also resulted in significant differences [30].

5. CONCLUSION

We can infer from this experiment that increased spacing, fruit thinning, and integrated nutrient management improve watermelon yield and yield-related characteristics. Given its improved production and yield-related features, D3F2N3 (spacing 1.0 m x 1.0 m, fruit thinning with 1 fruit per primary branch, and nutrient management with 50% RDF + 50% RDN through Vermicompost) may be considered the best treatment among the different interaction effects.

ACKNOWLEDGEMENT

Author is grateful to Department of Horticulture, College of Agriculture, Assam Agricultural University during period of his research work.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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