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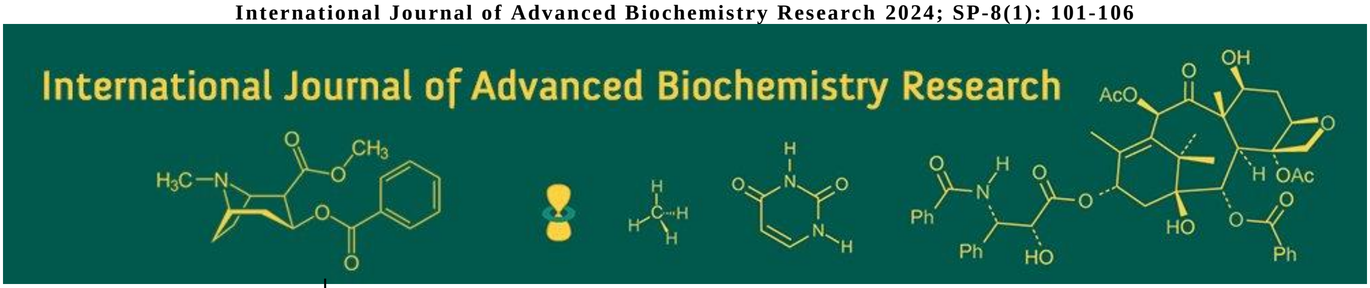

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Effect of crop geometry, fruit thinning and nutrient management on growth parameters of watermelon (*Citrullus lanatus* Thumb.)

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Abstract

The present investigation entitled "Standardization of crop geometry, fruit thinning and nutrient management in watermelon (*Citrullus lanatus* Thumb.)" was carried during 2020-21 in the farmer‘s field at Nahat Chapani village, Teok, in the district of Jorhat. The experiment was laid out in three factorial Randomized Block Design comprising thirty-six treatment combinations in three replications. The treatment details for all the three factors, *viz.*, Planting Density (D), Fruit thinning (F) and Integrated Nutrient Management (N) are as follows: Planting Density (D) [D 1: 2.50 m x 2.00 m (Recommended spacing), D 2: 1.50 m x 1.00 m, D 3: 1.00 m x 1.00 m]; Fruit thinning (F) [F 1: No fruit thinning, F 2: Fruit thinning (keeping 1 fruit per primary branch), F 3: Fruit thinning (keeping 2 fruit per primary branch)], Integrated Nutrient Management (N) [N 1: 100% RDF (inorganic) (60: 40: 60 kg NPK/ha), N 2: 50% RDF + 50% RDN through FYM, N 3: 50% RDF + 50% RDN through Vermicompost, N 4: 50% RDF + 25% RDN through FYM + 25% RDN through Vermicompost, (RDF-Recommended Dose of Fertilizers -60:40:60 kg of N, P_2O_5, K_2O per ha, respectively)]. The results of the experiment revealed that wider spacing and fruit thinning had positive impact on growth yield and quality of the Watermelon plants. Fruit thinning level F2 (Fruit thinning leaving 1 fruit per primary branch) is found to be best in terms of growth of watermelon. Integrated nutrient management improved the growth, yield and quality of fruits as well as soil properties. Among the levels, N3 (50% RDF + 50% RDN through Vermicompost) was found to be the best. .

Keywords: Crop geometry, fruit thinning, nutrient management, watermelon

Introduction

Watermelon (*Citrullus lanatus* (Thunb.) belongs to the genus *Citrullus* under the family cucurbitaceae. The crop is believed to be native to Africa and has spread worldwide (Dahake *et al.*, 2020) [1]. It is one among the important cucurbits which is cultivated widely and consumed by a large group of population around the world as fruit. Watermelon is a warm season annual cucurbit which is less tolerant to cold weather as compared to other fruits like Cucumber and Cantaloupe. Most of the varieties produce long prostrate vines and requires lots of horizontal space for good yield. The fruits are mainly used as a refreshing sources of tasty water and the crop uptakes a large volume of soil moisture for producing the juicy fruits (George, 2004) [2]. It is extensively grown in tropical and sub-tropical countries of Africa and Asia. As per FAO (2019) [3], around three fourth of the world‘s total production of watermelon is contributed by Asian countries. China is the leader with a total production of 79, 276, 300 tons with productivity of 42.88 t/ha. The other leading countries are Iran, Turkey, Brazil and Uzbekistan. The total production of watermelon in India during the year 2020-20 was around 3, 254, 000 MT from an area of 1, 19, 000 hectares (Anon., 2022) [4]. The crop is grown during *rabi* and summer season either as rainfed or irrigated conditions. The major watermelon growing states are Uttar Pradesh, Maharashtra, Karnataka, Tamil Nadu, Punjab, Rajasthan, Madhya Pradesh, Gujarat and Andhra Pradesh.

Crop geometry is one among the most important factors that plays remarkable role in crop production. Growth and yield of individual plants as well as crop stand per unit area is also influenced by crop geometry. Correct spacing enhances crop yield because it allows effective utilization of resources by plants and results in proper development of above and underground plant parts. Campagnol *et al.* (2016) [5] also reported that optimum spacing in watermelon allows a large leaf area, maximizes the interception of solar radiation and results in balanced distribution if metabolites between the vegetative and reproductive plant parts. Moreover, spacing can also influence the plant metabolism and crop cycle (Kavut *et al.*, 2014) [6]. Therefore, there is need optimization of spacing of watermelon to attain improved growth yield and quality of fruits.

Amid different crop management techniques used in melon production, those that influence the source /sink relationship have direct impact on the yield and quality of fruits. Fruit thinning is one of the important crop management techniques practiced in many crops to reduce the fruit load. Fruit thinning can be done by removal of certain flowers or fruitlets manually, mechanically, chemically and/or by combination of these methods. The main intention of fruit thinning is effectively maintaining the balance between vegetative growth and reproductive plant parts, *i.e.*, fruits (Anwar *et al.*, 2019) [7].

Watermelon responses well to the application of inorganic fertilizer and the dose depend upon the soil condition, climate and planting system. The vine length, number of branches and leaves as well as leaf area increase significantly due to increased dose of fertilizer (Lawal, 2000) [8]. Apart from the important major and micro nutrients the organic manures also supplies organic matters to soil. A proper blend of organic manures and inorganic fertilizers predictably supports the crop growth and yield (Kumar *et al.*, 2009) [9]. Principal sources of organic manure in India are FYM and Vermicompost. They also supply the essential plant nutrients, encourage the microbial activities and improve the physic- chemical properties of soil.

Therefore, keeping the above facts in mind the present investigation has been undertaken with the objectives to optimize the planting density and to study the effect of the crop load and integrated nutrient management on growth, yield and quality.

Materials and Methods

The present investigation was carried out during 2020-21 in the farmer‘s field at Nahat Chapani village, Teok, in the district of Jorhat. The experiment was laid out in three factorial Randomized Block Design comprising thirty-six treatment combinations in three replications. The treatment details for all the three factors, *viz*., Planting Density (D), Fruit thinning (F) and Integrated Nutrient Management (N) are as follows: Planting Density (D) [D 1: 2.50 m x 2.00 m (Recommended spacing), D 2: 1.50 m x 1.00 m, D 3: 1.00 m x 1.00 m]; Fruit thinning (F) [F 1: No fruit thinning, F 2: Fruit thinning (keeping 1 fruit per primary branch), F 3: Fruit thinning (keeping 2 fruit per primary branch)], Integrated Nutrient Management (N) [N 1: 100% RDF (inorganic) (60: 40: 60 kg NPK/ha), N 2: 50% RDF + 50% RDN through FYM, N 3: 50% RDF + 50% RDN through Vermicompost, N 4: 50% RDF + 25% RDN through FYM + 25% RDN through Vermicompost, (RDF-Recommended Dose of Fertilizers -60:40:60 kg of N, P_2O_5, K_2O per ha, respectively)].

Five plants per treatment in each replication were randomly selected and marked for recording the observations on vegetative, reproductive and physiological parameters. For the records of quality parameters one fruit each from the selected plants was again selected in random. To measure the leaf characteristics and to analyze the physiological parameters the fully opened fifth leaf in each selected plants was used (Ward, 1967) [10]. All the growth parameters like vine length, vine spread, number of primary branches, number of nodes per vine, leaf area and leaf area index etc. were recorded using different standard methods.

Results and Discussion

Vine length

Among the three different spacing levels studied, D_1 *i.e.* 2.5 m x 2.0 m recorded the highest vine length of 326.28 cm. Dantata (2014) [11] and Allah *et al.* (2022) [12] also reported similar findings in watermelon. The significant increase of vine length with increasing spacing may be due to the fact that the competition for nutrient, space, water and light was less in wider spacing as compared to the narrower spacing. It was hypothesized by Papadopoulos and Pararajasingham (1997) [13] that wider spacing provides more space to the plants for leaf expansion and reduces shading by surrounding plants. Thus, light interception by plants increases and, consequently more photosynthesis and greater individual growth (Peil *et al.*, 2014) [14].

Fruit thinning level F_2 *i.e.* Fruit thinning (keeping 1 fruit per primary branch) recorded the highest vine length of 284.41 cm. The highest vine length in F_2 may be because of increased availability of photo assimilates for vegetative growth because of less reproductive sink as compared to the other levels. This is in line with the findings of Moon and Kyun (1996) [15] and Fawzi *et al.* (2019) [16] in grapes.

Within the different levels of nutrient management, N_3 (50% RDF + 50% RDN as Vermicompost) recorded the highest vine length of 297.64 cm, whereas N_1 (100% RDF – inorganic fertilizers) recorded the lowest length of 263.80 cm. Incorporation of vermicompost might have increased the microbial and enzymatic activity in soil resulting increased bio availability of nutrients, especially nitrogen which enhanced the cell division and cell elongation. This may be the reason behind the longest vine production in case of N_3. The results of present investigation are in agreement with the findings of Ghosh *et al.* (2016) [17], Tahir *et al.* (2018) [18], Sonkamble *et al.* (2022) [19] and Sai *et al.* (2022) [20] in watermelon; Atiyeh *et al.* (2002) [21], Bindiya *et al.* (2014) [22] and Singh *et al.* (2020) [23] in cucumber.

Significant differences among the interactions were also recorded. The highest vine length (338.55 cm) was recorded in treatment T_7 ($D_1F_2N_3$) which was at par with treatment T_3 ($D_1F_1N_3$), T_8 ($D_1F_2N_4$) and T_{11} ($D_1F_3N_3$). The treatment T_{25} ($D_3F_1N_1$) and T_{33} ($D_3F_3N_1$) recorded the lowest vine length of 218.56 cm. Significant difference in the interaction effect might be the result of complementary effect of spacing, fruit thinning and nutrient management.

Number of primary vines

Number of primary vines as affected by spacing, fruit thinning and nutrient management has been presented in Table 1(a) and 1(b). It can be inferred from the table that spacing, fruit thinning and nutrient management had significant effect on the number of vines produced by plants. Spacing level D_1 recorded the maximum (6.45) vines per plant and the minimum (5.28) vines per plant were produced by plants in spacing level D_3 (1.00 m x 1.00 m).The present finding is in consonance with the reports of Adlan and Sarra (2018) [24] and Allah *et al.* (2022) [12] in watermelon. The competition for nutrient, space and light is less in wider spacing as compared to the narrower spacing which helps in better incorporation of light and more photosynthesis. This may be the reason behind production of more vines per plant in wider spacing. Campagnol *et al.* (2016) [5] also opined that wider spacing results in availability of more volume of soil per plant to explore. At the same time availability of horizontal space is also more compared to narrower spacing. Consequently, the leaves capture more luminous radiation, increases photosynthetic ability of plants and more accumulation of biomass.

In the case of fruit thinning, F_2 recorded the highest number of vines of 5.93, which was significantly higher than the lowest number recorded in F_1 (5.81). Fruit thinning reduces load of reproductive sink in plants as compared to the plants without fruit thinning. This may increase the availability of photo assimilates for more vegetative growth. These results are in line with the findings of Anwar *et al.* (2019) [7] in watermelon.

Similarly, in the case of the nutrient management, N_3 (6.12), recorded the highest number of vines per plant, though it was at par with N_4 (5.92). Application of organic manures in the form of Vermicompost and FYM might have improved the physic-chemical condition and water holding capacity of soil. This might led to adequate supply of nutrients resulting the production of more vines per plant. The results are in agreement with the findings of Sonkamble *et al.* (2022) [19] in watermelon; Thriveni *et al.* (2015) [25] in bitter gourd; Das *et al.* (2015) [26], Singh *et al.* (2017) [27] and Singh *et al.* (2018) [28] in bottle gourd; Anjanappa *et al.* (2012) [29], and Singh *et al.* (2018) [28] in cucumber; Nayak *et al.* (2016) [30] in pointed gourd and Bindiya *et al.* (2012) [22] in gherkin.

The interaction effect of the factors was also significant. Among the interactions, T_{11} ($D_1F_3N_3$) exhibited the highest number of vines (6.64) that was at par with T_7 ($D_1F_2N_3$) and T_{25} ($D_3F_1N_1$) recorded the lowest number of vines (4.90). Significance in the interaction effect might be the result of complementary effect of spacing, fruit thinning and nutrient management.

Vine spread

Table 1(a) and 1(b) represents the influence of spacing, fruit thinning and nutrient management on the vine spread. The significant effect on vine spread is evident from the tables.

The highest vine spread (292.71 cm and 303.45 cm) in E-W and N-S directions respectively was seen in D_1. The significant increase of vine spread in wider spacing may be due to the production of longer vines and availability of more horizontal space as compared to the narrower spacing. It was hypothesized by Papadopoulos and Pararajasingham (1997) [13] that wider spacing provides more area to the plants for leaf expansion and reduces shading by surrounding plants. Thus, light interception by plants increases and, consequently more photosynthesis and greater individual growth occurs (Peil *et al.*, 2014) [14]. Bellad and Umesh (2018) [31] and Anwar *et al.* (2019) [7] also reported similar findings in watermelon.

In case of fruit thinning F_2 recorded the highest vine spread of 257.87 cm and 269.92 cm respectively in E-W and N-S directions. As the vine length increased due to fruit thinning, the vine spread may also have increased. Increased availability of photo-assimilated for vegetative growth due to reduced fruit load may be the reason behind.

On observing the effect of nutrient management, 268.16 cm in E-W and 281.17 cm in N-S directions were the maximum vine spread seen in case of $N_{3,}$ whereas N_1 recorded the lowest spread. Combined application of organic manures and inorganic fertilizers resulted in better vegetative growth and production of longer vines. This may be the reason behind the highest vine spread in case of N_3.

Within the interactions, T_7 ($D_1F_2N_3$) recorded the highest of 307.72 cm and 316.07 cm spread in E-W and N-S directions respectively. The lowest vine spread in E-W direction was 205.59 cm and that in N-S direction was 208.84 cm. It was recorded in the treatment T_{25} ($D_3F_1N_1$). The significant variations in interaction may be the result of cumulative effect of all the three factors together.

Number of nodes per vine

The results regarding the effect of spacing, fruit thinning and nutrient management on number of nodes per vine is depicted in Table 1(a) and 1(b). It is seen that effect of spacing and nutrient management was significant. But no significant influence was observed due to fruit thinning.

Number of nodes increased linearly with the increase in spacing and the maximum (41.08) nodes were produced in D_1. The minimum (32.56) nodes per vine were recorded in D_3. The significant increase in number nodes per vine in wider spacing may be due to the production of longer vines as compared to that in closer spacing. Similar findings were reported by Ayene *at al.* (2021) [32] in golden melon and (Ban *et al.*, 2011) [33] in watermelon.

Table 1 a): Influence of spacing, fruit thinning and nutrient management on growth parameters of Watermelon

Treatments	Vine length (cm)	Number of vines	Vine spread NS (cm)	Vine spread EW (cm)	Nodes per vine	Leaf area index
D_1	326.28	6.45	303.45	292.71	41.08	0.112
D_2	279.84	5.90	269.79	252.72	36.92	0.339
D_3	236.11	5.28	227.65	219.34	32.56	0.454
S.Em. (±)	1.01	0.05	1.31	0.76	0.38	0.001
CD (0.05)	2.84	0.13	3.70	2.13	1.08	0.003
F_1	276.98	5.81	264.23	252.04	36.50	0.299
F_2	284.41	5.93	269.92	257.87	37.19	0.305
F_3	280.84	5.88	266.75	254.86	36.88	0.301
S.Em. (±)	1.01	0.05	1.31	0.76	0.38	0.001
CD (0.05)	2.84	0.13	3.70	2.13	NS	0.003
N_1	263.80	5.65	253.73	242.16	35.28	0.290
N_2	273.97	5.80	261.62	250.37	36.31	0.297
N_3	297.64	6.12	281.17	268.16	38.38	0.313
N_4	287.57	5.92	271.34	259.00	37.45	0.306
S.Em. (±)	2.13	0.10	2.78	1.60	0.81	0.002
CD (0.05)	6.01	0.27	7.85	4.52	2.29	0.006

Table 1 b): Influence of interaction of spacing, fruit thinning and nutrient management on growth parameters of Watermelon

Treatments	Vine length	No. of vines	Vine spread NS (cm)	Vine spread EW (cm)	Nodes per vine	Leaf area index
T_1: $D_1F_1N_1$	311.45	6.22	290.83	277.41	39.42	0.108
T_2: $D_1F_1N_2$	319.41	6.37	296.81	285.11	40.35	0.110
T_3: $D_1F_1N_3$	334.70	6.57	311.81	302.69	42.20	0.115
T_4: $D_1F_1N_4$	328.57	6.40	305.54	294.62	41.15	0.113
T_5: $D_1F_2N_1$	317.29	6.29	296.21	281.72	39.93	0.110
T_6: $D_1F_2N_2$	326.57	6.41	303.06	292.82	40.93	0.112
T_7: $D_1F_2N_3$	338.55	6.76	316.07	307.72	42.72	0.117
T_8: $D_1F_2N_4$	333.11	6.50	308.16	298.35	41.94	0.114
T_9: $D_1F_3N_1$	314.26	6.30	294.67	278.88	39.63	0.109
T_{10}: D1F3N2	322.93	6.42	298.82	290.10	40.78	0.111
T_{11}: D1F3N3	336.91	6.64	312.46	305.82	42.29	0.115
T_{12}: D1F3N4	331.65	6.47	307.01	297.24	41.61	0.114
T_{13}: D2F1N1	256.83	5.66	252.61	235.36	34.78	0.323
T_{14}: D2F1N2	262.22	5.82	263.07	243.01	35.61	0.331
T_{15}: D2F1N3	297.71	6.06	282.62	265.55	38.28	0.353
T_{16}: D2F1N4	279.63	5.83	269.59	254.35	37.11	0.341
T_{17}: D2F2N1	260.12	5.75	261.10	240.43	35.24	0.329
T_{18}: D2F2N2	278.22	5.86	266.07	248.12	36.73	0.338
T_{19}: D2F2N3	308.00	6.19	287.83	272.49	39.25	0.356
T_{20}: D2F2N4	293.55	6.01	277.92	264.65	38.03	0.350
T_{21}: D2F3N1	257.70	5.71	256.00	238.29	34.89	0.325
T_{22}: D2F3N2	273.80	5.80	265.14	246.62	36.52	0.336
T_{23}: D2F3N3	302.64	6.12	284.17	267.91	38.83	0.346
T_{24}: D2F3N4	287.63	5.95	271.41	255.90	37.79	0.346
T_{25}: D3F1N1	218.56	4.90	208.84	205.59	31.03	0.431
T_{26}: D3F1N2	222.44	5.13	216.42	214.11	31.63	0.442
T_{27}: D3F1N3	250.76	5.50	242.10	227.03	33.56	0.470
T_{28}: D3F1N4	241.49	5.30	230.50	219.69	32.89	0.455
T_{29}: D3F2N1	219.45	5.06	213.01	213.05	31.41	0.440
T_{30}: D3F2N2	233.92	5.25	224.57	217.48	32.37	0.449
T_{31}: D3F2N3	255.81	5.61	247.74	233.56	34.31	0.477
T_{32}: D3F2N4	248.33	5.47	237.30	224.08	33.36	0.467
T_{33}: D3F3N1	218.56	4.95	210.28	208.70	31.21	0.438
T_{34}: D3F3N2	226.18	5.17	220.63	215.97	31.86	0.446
T_{35}: D3F3N3	253.66	5.61	245.75	230.67	33.96	0.471
T_{36}: D3F3N4	244.19	5.39	234.67	222.16	33.17	0.459
S.Em. (±)	4.27	0.19	5.56	3.21	1.62	0.004
CD (0.05)	12.03	0.54	15.69	9.04	4.57	0.012

Integration of organic manures with inorganic fertilizers resulted in increased number of nodes per vine. N_3 recorded the highest (38.38) number which was at par with N_4 (37.45), while the lowest (35.28) number of nodes per vine was found in N_1. Balanced vegetative growth resulted by integration of organic sources of nutrients may be the reason behind more number of nodes per vine.

The interaction effect was found to be significant. Treatment T_7 ($D_1F_2N_3$) recorded the highest (42.72) number of nodes per vine and the least (31.03) was seen in T_{25} ($D_3F_1N_1$). This may be because of combined effect of significant variations recorded due to spacing, fruit thinning and nutrient management individually.

Leaf area

On observing the data in Tables 1(a) and 1(b) it could be concluded that leaf area was significantly influenced by spacing, fruit thinning, nutrient management and their interactions.

In case of spacing the highest leaf area was exhibited by D_1 (5603.83 cm^2) and in case of fruit thinning, F_2 recorded the highest (5124.56 cm^2). More horizontal space was available in wider spacing. This resulted in less competition for space, nutrient and light helping in better photosynthetic activity, giving more vegetative growth and leaf area. The result is in line with the findings of Gomes *et al.* (2017) [34]. and da Silva *et al.* (2021) [35] in watermelon. The increase in leaf area due to fruit thinning may be attributed to the better vegetative growth recorded. Silva *et al.* (2019) [36] in watermelon; Moon and Kyun (1996) [15] and Fawzi *et al.* (2019) [16] also reported the increase in leaf area of grapes due to fruit thinning.

On studying the effect of nutrient management, $N_3$was found to have the highest (5255.59 cm^2) leaf area followed by N_4 (5148.63 cm^2) and the lowest was found in N_1 (4894.00 cm^2). Leaf area of plants is mainly governed by genotype and nutrition. Balanced nutrition provided by integrated nutrient management may be the reason behind better vegetative growth and increased leaf area.

Upon observing the interaction effect, it was seen that T_7 ($D_1F_2N_3$) recorded the highest (5817.00 cm^2) leaf area, while T_{25} ($D_3F_1N_1$) recorded the lowest (4311.33 cm^2). Significance in the interaction effect might be the result of complementary effect of spacing, fruit thinning and nutrient management

Leaf Area Index (LAI)

It can be inferred from Table 1(a) and 1(b) that spacing, fruit thinning, nutrient management and their interaction significantly affected the Leaf Area Index (LAI).

LAI increased with the decrease in spacing and crop load. The highest (0.45) LAI was recorded in spacing D_3 (1.0 m x

1.0 m), while in D_1it was lowest (0.11). Higher plant population in closer spacing may have resulted in the increased LAI as compared to wider spacing. In case of fruit thinning F_2 recorded the highest LAI of 0.31 and the least was recorded in F_1. This may be due to the higher leaf area recorded due to thinning of fruits. It was seen that incorporation of organic sources of nutrients had positive effect on LAI. N_3 recorded the highest LAI of 0.31 and in N_1 it was the lowest (0.29). This may be due to the higher leaf area in N_3 as compared to others. Positive effects of INM on growth parameters were reported by Thriveni *et al.* (2015) [25] in bitter gourd; Das *et al.* (2015) [26], Singh *et al.* (2017) [27] and Patle *et al.* (2018) [37] in bottle gourd; Singh *et al.* (2018) [28] in cucumber and Nayak *et al.* (2016) [30] in pointed gourd.

Further studying the interactions, $D_3F_2N_3$ (T_{31}) recorded the highest LAI of 0.48 and $D_1F_1N_1$ (T_1) recorded the least of 0.11. Interactions of $D_3F_1N_3$ (T_{27}) and $D_3F_2N_3$ (T_{35}) recorded values at par with $D_3F_2N_3$ (T_{31}). The significant variations in interaction may be the result of cumulative effect of all the three factors together.

Conclusion

Wider spacing resulted in better growth of the Watermelon plant. Fruit thinning had positive impact on growth yield and quality. Fruit thinning level F2 (Fruit thinning leaving 1 fruit per primary branch) is found to be best in terms of growth of watermelon. Integrated nutrient management improved the growth, yield and quality of fruits as well as soil properties. Among the levels, N3 (50% RDF + 50% RDN through Vermicompost) was found to be the best.

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