

Original Research Article

Evaluation of Integrated Nutrient Management for Mandarin Orange Production in Hot Humid Region of Bangladesh

ABSTRACT

The study was aimed at boosting up the yield and profitability of mandarin orange cultivation through integrated nutrient management. ~~Experiment was conducted for three consecutive years viz. 2012, 2013 and 2014 with mandarin variety BARI Mandarin-1.~~ [BF1] The experiment consists of six treatments laid out in a randomized complete block design. Data were recorded on growth, yield, quality and profitability. All the parameters were influenced by different integrated nutrient approaches. ~~Most of the growth, yield and qualitative parameters were found to be influenced by different nutrient management options. At most from the plants~~ Plants receiving received 60% of their required nutrients as per soil test basis from chemical fertilizer and 40% from Cow dung (T₄) were found best with yield and qualitative parameters along with the highest marginal rate of return. [BF2] Hence, this management option may be a wise and economic choice for farmers producing mandarin orange var. BARI Mandarin-1 production in hot humid tropical region of Bangladesh.

Keywords: Mandarin oranges, integrated nutrient management, yield, profitability

1. INTRODUCTION

~~Integrated nutrient management shows the way to administrate the soil efficiently with regards to its physical, hydrological, chemical and biological characteristics towards all available plant nutrient sources, organic and inorganic, to provide optimum and sustainable productivity as well as conserving soil health conservation as well as maximizing crop productivity [1], as soil health problem is exacerbating, targeting to accelerate food production for escalating population.~~ [BF3] Mandarin (*Citrus reticulata* Blanco) is a popular minor fruit in Bangladesh. It is a tasty fruit having nutritional and medicinal value [2] also rich in vitamin A, B and C (40 mg/100 g juice) with recognized immense economic importance.

The north eastern hilly region of Bangladesh is characterized with small hills and hillocks, wet summer and dry winter [3] where mandarin is an important crop mostly produced in homesteads, some commercial orchards also found. However, the productivity is not up to the mark in comparison with other mandarin growing countries. The main reasons for low productivity are lack of high yielding varieties, low inputs and imbalanced use of nutrients, poor management of soil and water resources, inadequate management of major insect pests, mite, diseases and weeds, rainfed conditions and surging topography, shallow soil depth and low pH of the soil [2].

Bangladesh Agricultural Research Institute has already released two varieties of mandarin orange for commercial cultivation. Hence the problem for high yielding variety is partially solved but farmers are not interested with modern cultivation and cultural practices rather than indigenous. The indigenous people "the Khasias" used to produce mandarin without

using fertilizers. High rainfall (Average 6000 mm approximately per Annam) [4] leads to leaching of minerals from soil turning it to acidic in nature (pH 4.5 to 4.8 on an average). Therefore, the commercial mandarin orchards as well as the homestead trees are facing severe nutrient deficiency. Profitability in addition to soil conservation is however be achieved noticeably through judicious nutrient management. Better growth, yield, and quality of different citrus fruits can be obtained by thoughtful use of organic and inorganic fertilizers by several workers [5, 6, 7, 8]. Huchche et al. found increased yield of Mandarin in the course of applying organic amendments to soil with different chemical fertilizers [9]. Significant growth, yield and quality of citrus fruit were also found by other researchers with definite role of N, P, Mg, Zn, and B in India [10]. Thus, various fruit crops found to respond positively to organic manures and inorganic fertilizers (the cheap available nutrient source) on growth, yield and quality [11].

But, very few systematic works on the nutritional requirement of mandarin in the hilly region of Bangladesh has been carried out and no one on integrated nutrient management. The present research was therefore, conducted to evaluate the impact of integrated nutrient management on mandarin production. Our objectives were to study the effects of application of organic manure (cow dung) in combination with inorganic fertilizers to boost the yield and profitability.

2. MATERIAL AND METHODS

2.1. ~~Field trial~~ Experimental site

The experiment was conducted at Citrus Research Station, Bangladesh Agricultural Research Institute (BARI), Jaintiapur, Sylhet (25.13562° N latitude, 92.13217 ° E longitude, 36m of elevation from mean sea level), Bangladesh in three consecutive years viz. 2012, 2013 and 2014. ~~Mandarin variety BARI Mandarin 1 as scion variety budded on rough lemon (*Citrus jambhiri* Lush) and we used for the study. The plants were planted in square planting system with 3×3 m spacing in the year of 2005.~~ The climatic condition of the experimental location was subtropical in nature, which is characterized with the pre monsoon (March to April), the monsoon (May to September) and the winter or dry season (November to February). Annual average rainfall ranges from 4500-6000 mm, the mean maximum and minimum temperatures are 36°C and 6°C in the month of April and January respectively. The soil of the experimental plot belongs to northern and eastern piedmont plains (AEZ 22 of Bangladesh) having sandy loam textured soil [9].

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2.2. Designing experimental treatments

The physico-chemical properties of the soil were analyzed before every experimental year for knowing the recommended fertilizer dose of nutrients for mandarin on soil test basis (STB) of study using standard procedures. Soil samples were collected from the depth of 0-20 cm of experimental field in all the years. At the very beginning of the study the soil was with pH 4.8 and organic carbon 1.28 per cent. Amount of N, K, S, Ca and Mg for growing mandarin were also found to be low (Table 1). Hence, dolomite 4kg/decimal was applied to regulate the pH level of the soil. The other nutrients were applied as per treatment.

The experiment consists of six treatments viz. For moderate yield goal the amount of macro-nutrients required for mandarin orange cultivation was $N_{100}P_{26}K_{160}S_6$ kg/ha on STB. As our objective was to implement integrated nutrient management therefore these particular dose was supplied to the plants from organic and inorganic sources in combined and sole and . Thus, six treatments were set as follows. T_1 = 100% Recommended Dose (RD) of nutrients as per STB (Soil test basis) from Chemical fertilizer, T_2 = 125% RD of nutrients as per STB

from Chemical fertilizer, T_3 = 80% RD of nutrients from Chemical fertilizer + 20% from Cow dung, T_4 = 60% RD of nutrients from Chemical fertilizer + 40% from Cow dung, T_5 = Existing Practice (100% RD of nutrients as per STB (Soil test basis) from Cow dung), T_6 = Native nutrient (Control). [BF5]

Table 1. Soil test results of the experimental plot for three consecutive years [BF6]

Parameters	Experimental year					
	2012	Remarks	2013	Remarks	2014	Remarks
pH	4.8	Very acidic	5.8	Acidic	5.4	Acidic
Organic Matter (%)	1.67	Low	1.8	Low	1.85	Low
N (% Total)	0.141	Low	0.152	Low	0.155	Low
P ($\mu\text{g/ml}$)	18.1	Optimum	19.1	Optimum	19.5	Optimum
K (meq/100ml)	0.07	Low	0.08	Low	0.08	Low
S ($\mu\text{g/ml}$)	12.0	Low	12.2	Medium	12.4	Medium
Ca (meq/100ml)	1.6	Low	5.5	Optimum	4.5	Medium
Mg (meq/100ml)	0.68	Low	1.12	Optimum	1.09	Medium
B ($\mu\text{g/ml}$)	0.26	Medium	0.25	Medium	0.25	Medium
Zn ($\mu\text{g/ml}$)	1.25	Optimum	1.19	Optimum	1.18	Optimum
Cu ($\mu\text{g/ml}$)	0.45	Optimum	0.44	Optimum	0.41	Optimum
Fe ($\mu\text{g/ml}$)	12.2	Very high	12.2	Very high	12.1	Very high
Mn ($\mu\text{g/ml}$)	2.2	Optimum	2.0	Optimum	2.0	Optimum

Table 2. Amount of different macronutrient elements applied as per treatments on three study [BF7] years.

treatments	Nutrient elements (g/plant)											
	N			P			K			S		
	Experimental year											
	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014
T ₁	90	85	83	24	20	18	145	137	137	6	6	6
T ₂	112.5	106.25	103.75	30	25	22.5	181.25	171.25	171.25	7.5	7.5	7.5
T ₃	90	85	83	24	20	18	145	137	137	6	6	6
T ₄	90	85	83	24	20	18	145	137	137	6	6	6
T ₅	90	85	83	24	20	18	145	137	137	6	6	6
T ₆	0	0	0	0	0	0	0	0	0	0	0	0

2.23. Cultural management

Mandarin variety BARI Mandarin-1 as scion variety budded on rough lemon (*Citrus jambhiri* Lush) and we used for the study. The plants were planted in square planting system with 3×3 m spacing in the year of 2005.

Fertilizer was applied as per treatment; Dolomite (agricultural lime) 4 kg/decimal was applied only in the first year of experiment in every treatment for managing soil pH. [BF8] Full quantity of cow dung was applied to all the plants after harvest during November along with complete dose of phosphorus, sulfur and half of potassium. Nitrogen and other half of potassium were applied in three equal installments during November, April and June. Macronutrients N, P, K and S were applied to the plant as urea, triple super phosphate, muriate of potash, and gypsum respectively as per treatments. [BF9] Fertilizers were applied radially 45 cm away from trunk, and light spading was performed for mixing the fertilizers with the soil properly. The plants were irrigated from mid December to mid March at an interval of 15 days for proper flowering and fruit retention. The plants were infested with leaf miner and lemon butterfly twice in the fruiting period and controlled spraying imidachlopid. No plant disease was observed during the fruiting period. Fruits were shaded by white mosquito net during October-November to protect them from sun burn.

2.34. Growth, yield attributes and yield measurement

Data were recorded on growth parameters namely, viz. [BF10] percent growth in plant height, plant volume (m^3), fruits per plant, yield per plant (kg) and yield efficiency (kg/m^3). Following Castle et al. [12] through minor amendment, tree volume were calculated via the formula $V (m^3) = \pi / 6 \times H \times D^2$ where, V was plant volume, H was plant height and D was the average value of north-south and east-west spreading of the canopy [12]. Yield ($kg/plant$) was recorded on every commercial harvest. Yield efficiency (Kg/m^3) was computed from the relationship between fruit yield ($kg/plant$) and tree volume (m^3). The relationship between yield efficiency and tree volume was analyzed by a regression model [13].

2.45. Harvesting and fruit quality measurement

In every experimental year mature fruits were collected from the plants on last week of October near third week of November. Ten fruits from each plant were harvested randomly for data collection on individual fruit weight (g), Fruit size (length and diameter at equatorial region), segments per fruit, seeds per fruit, seed weigh per fruit, rind weigh, percent juice content, total soluble solids (TSS), titratable acidity (TA) and Maturity index. Juice was extracted from the pulp of each fruit and expressed as the relationship between the weights of the extracted juice with the weight of fruit to calculate percent juice content [14]. Total soluble solids content (TSS) was measured with the help of refracto-meter and corrected with temperature factor [15]. By titrating 10 ml juice with 0.1 M NaOH, titratable acidity (TA) was measured [14]. Maturation index (MI), calculated by the ratio of TSS:TA [16].

2.5-6. Economic analysis

Profitability of mandarin production was estimated using partial budget [2]. Partial budget was investigated determining the most cost-efficient satisfactory treatment, by estimating the gross value of the crop (fruits) using the adjusted yield at orchard gate price for the fruits and local price of inputs [17]. Also the customary wages paid to agricultural farm labourers at the locality were used for estimating the varied cost of labourers. Dominance analysis was then performed based on the net benefit and the variable costs, compared among the treatments on the principle that any nutrient management option which had net benefit less or identical to that of another option with inferior charge is dominated and such option won't be considered by the cultivator [18].

After identification of the dominated one only undominated [BF11] (any nutrient management option which had more net benefit from that of another with inferior charge) treatments were taken for, marginal analysis in a sequential way, starts from one treatment with the highest costs that vary to the next. Marginal rate of return (%) was calculated for each couple of ranked undominated treatments. Therefore, marginal rate of return (MRR) was measured calculated by the relationship between the change in net benefit and change in total cost that varies, expressed to percentage using the following formula [18]:

$$MRR = (\Delta NB) / \Delta TVC \times 100$$

Where, MRR = Marginal rate of return in percentage, NB = Change in net benefits, TVC = Change in total variable cost

Usually, a minimum marginal rate of return (MRR) rate of return of 50% is acceptable for the farmers to shift from one nutrient management option to other devoid of without learning fresh skills [BF12]. Thus, any treatment that gave MRR exceeding 50% is considered admirable for farmers' investment [17, 18, 19].

2.6-7. Experimental design and Data Analysis

The experiment was laid out in randomized block design with different treatment combinations being replicated five times. All the recorded data on different parameters were statistically analyzed using MSTAT-C programme and Duncan's Multiple Range Test [BF13] was performed for mean separations of the studied parameters and interpretation of results [20].

[BF14]

3. RESULTS AND DISCUSSION

3.1. Height and tree volume

The height and tree volume of mandarin variety BARI Mandarin-1 was clearly affected by the nutrient management options (Table 3 Figure 1 & 2). In the first year of study, the plants received 60% of required nutrients as per soil test basis (STB) from chemical fertilizer and 40% from Cow dung (T₄) grows vigorously and reached up to 193.4 cm in height on an average with 2.71 m³ of tree volume, which was also emulated in the second year of the study (212.8 cm height and 3.58 m³ of tree volume respectively). But in the third year of study more vigourity (235.0 cm height and 4.36 m³ of tree volume) was found from the plants received 80% of required nutrients as per STB from chemical fertilizer and 40% from Cow dung (T₃). While comparatively weak plants was found from the plants grows on soil's native nutrients (T₆). In all three years of experiment, T₁ and T₂ showed intermediate vigor.

Table 3. Effect of integrated nutrient supply on height and plant volume of nth and yield of mandarin oranges [BF15]

Treatments	Plant height (cm)			Tree volume (m ³)		
	2012	2013	2014	2012	2013	2014
T ₁	182.6 bc	201.8 b	215.6 bc	2.11 bc	2.79 c	3.63 c
T ₂	188.2 ab	201.8 b	219.8 b	2.13 bc	2.94 c	4.08 b
T ₃	188.6 ab	211.2 a	235.0 a	2.28 b	3.34 ab	4.36 a
T ₄	193.4 a	212.8 a	228.8 a	2.71 a	3.58 a	4.29 a
T ₅	178.0 c	192.8 c	205.6 c	2.20 bc	3.25 b	4.27 ab
T ₆	176.2 c	186.4 c	196.4 d	1.89 c	2.72 c	3.27 d
LSD	8.69	8.11	8.63	0.34	0.25	0.19
CV%	2.59	02.22	2.18	8.57	4.55	2.78

In a column means followed by common letters are not significantly different from each other at 5 & 1 % level of probability by DMRT.

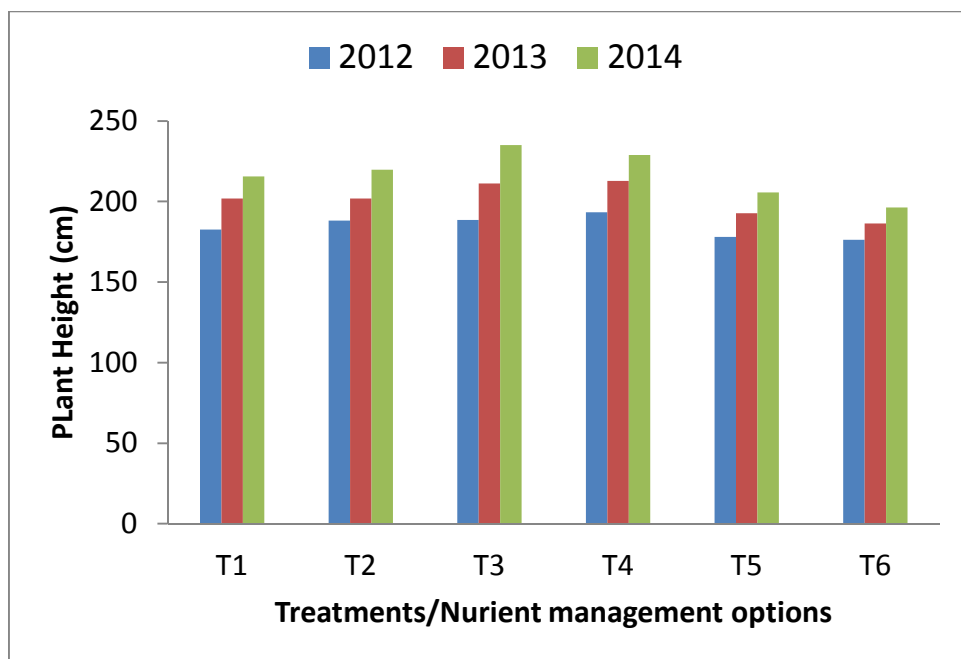


Figure 1. Effect of integrated nutrient supply on height of mandarin oranges trees

T₁= 100% Recommended Dose(RD) of nutrients as per STB (Soil test basis) from Chemical fertilizer, T₂ = 125% RD of nutrients as per STB from Chemical fertilizer, T₃ = 80% RD of nutrients from Chemical fertilizer + 20% from Cow dung, T₄= 60% RD of nutrients from Chemical fertilizer+40% from Cow dung, T₅= Existing Practice (100% RD of nutrients as per STB (Soil test basis) from Cow dung), T₆= Native nutrient (Control)

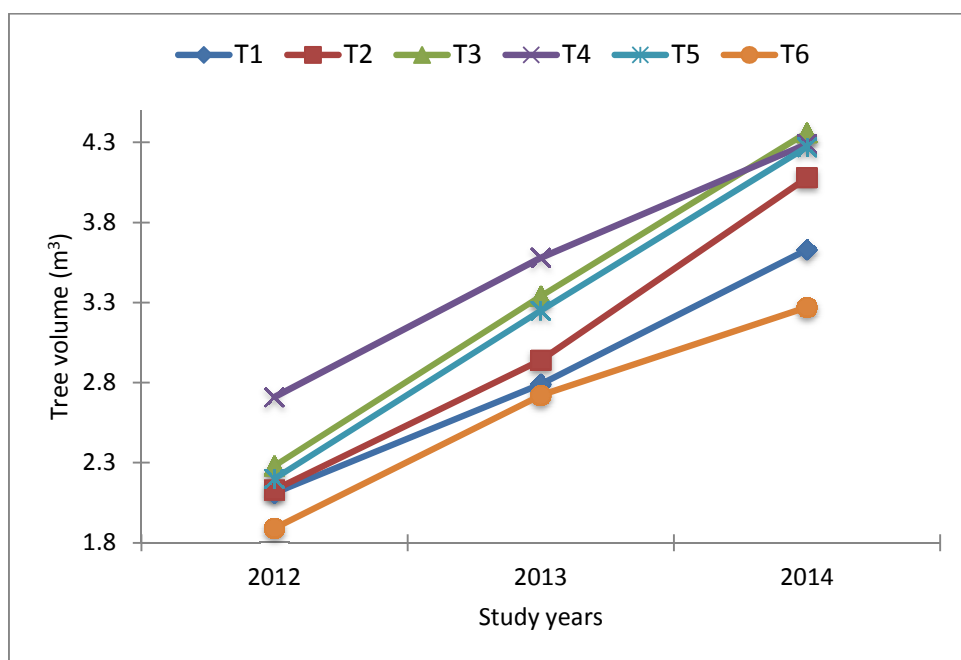


Figure 2. Effect of integrated nutrient supply on tree volume of mandarin oranges plants

T₁= 100% Recommended Dose(RD) of nutrients as per STB (Soil test basis) from Chemical fertilizer, T₂ = 125% RD of nutrients as per STB from Chemical fertilizer, T₃ = 80% RD of nutrients from Chemical fertilizer + 20% from Cow

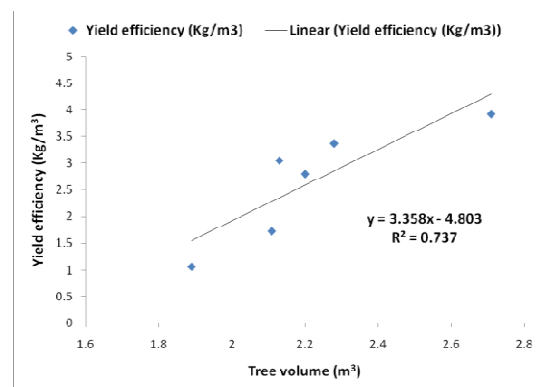
211 dung, T₄= 60% RD of nutrients from Chemical fertilizer+40% from Cow dung, T₅= Existing Practice (100% RD of
 212 nutrients as per STB (Soil test basis) from Cow dung), T₆= Native nutrient (Control)
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214 3.2. Yield

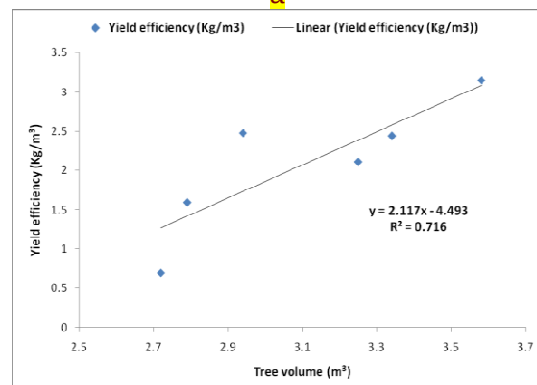
215 Effects of integrated nutrient supply showed similar momentous variations on yield
 216 characters also. In all the experimental years less productivity was obtained from the control
 217 treatment where the plants grown under native nutrient status of soil (T₆). These plants
 218 retained less number of fruit with comparatively small fruit (data not presented) of lower
 219 individual fruit weight resulting little yield per plant and lower yield efficiency (Figure 23).
 220 Throughout the experiment maximum number of fruit, yield and yield efficiency was carried
 221 by the plants received 60% recommended nutrients as per STB from Chemical fertilizer and
 222 40% from Cow dung (T₄) demonstrating the influence of integrated management together
 223 with organic and inorganic nutrients at par with the plants received 80% recommended
 224 nutrients as per STB from Chemical fertilizer and 20% from Cow dung (T₃). However, use of
 225 chemical fertilizers solely (T₁) or even in higher dose than recommendation (T₂) didn't give a
 226 significant variation respect to fruits per plant, yield and yield efficiency.
 227

228 ~~A significant positive linear relationship between yield efficiency and plant volume (Figure-~~
 229 ~~1a, 1b and 1c) confirmed the superior performance regards to yield efficiency~~
 230 ~~(Kg/m³) was found from of T₄ (60% recommended nutrients as per STB from Chemical~~
 231 ~~fertilizer and 40% from Cow dung) although decreased through out the experimental period~~
 232 ~~(Figure 4). for producing mandarin orange BARI Mandarin-1, Whereas differing from the~~
 233 ~~least productive yield efficiency was found from T₆ (Native nutrient) in all the experimental~~
 234 ~~years (2012, 2013 and 2014 respectively).~~
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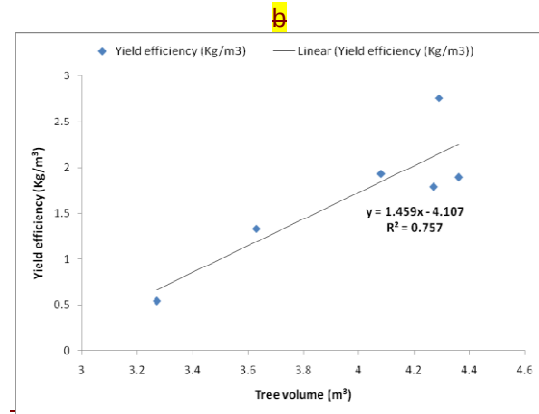
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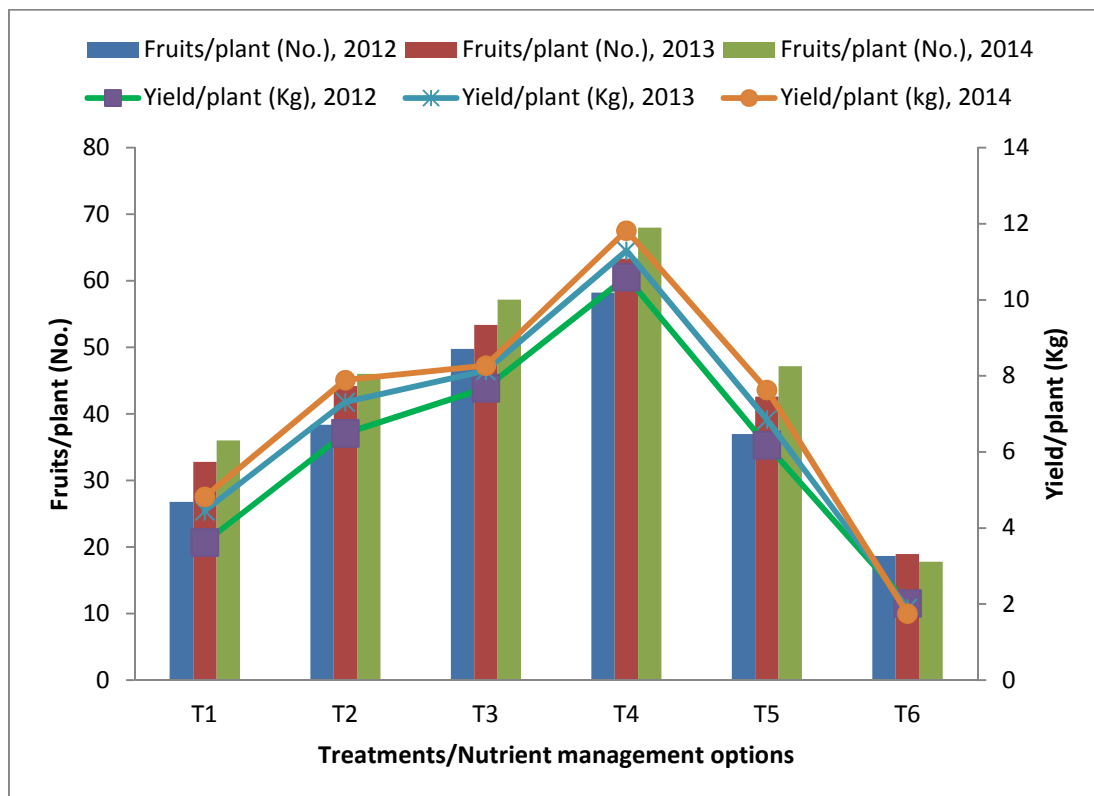
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Fig. 1(a, b, c). Relationship between yield efficiency (kg/m³) and canopy volume (m³) of 'BARI-Mandarin-1' grown under integrated nutrient management (2012, 2013 & 2014) [BF17]



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Figure 23. Number of fruits per plant and per plant yield (g) of BARI-KamalaMandarin-1 as influenced by different levels and forms of integrated nutrient applications supply

T₁= 100% Recommended Dose(RD) of nutrients as per STB (Soil test basis) from Chemical [BF18] fertilizer, T₂ = 125% RD of nutrients as per STB from Chemical fertilizer, T₃ = 80% RD of nutrients from Chemical fertilizer + 20% from Cow dung, T₄= 60% RD of nutrients from Chemical fertilizer+40% from Cow dung, T₅= Existing Practice (100% RD of nutrients as per STB (Soil test basis) from Cow dung), T₆= Native nutrient (Control)

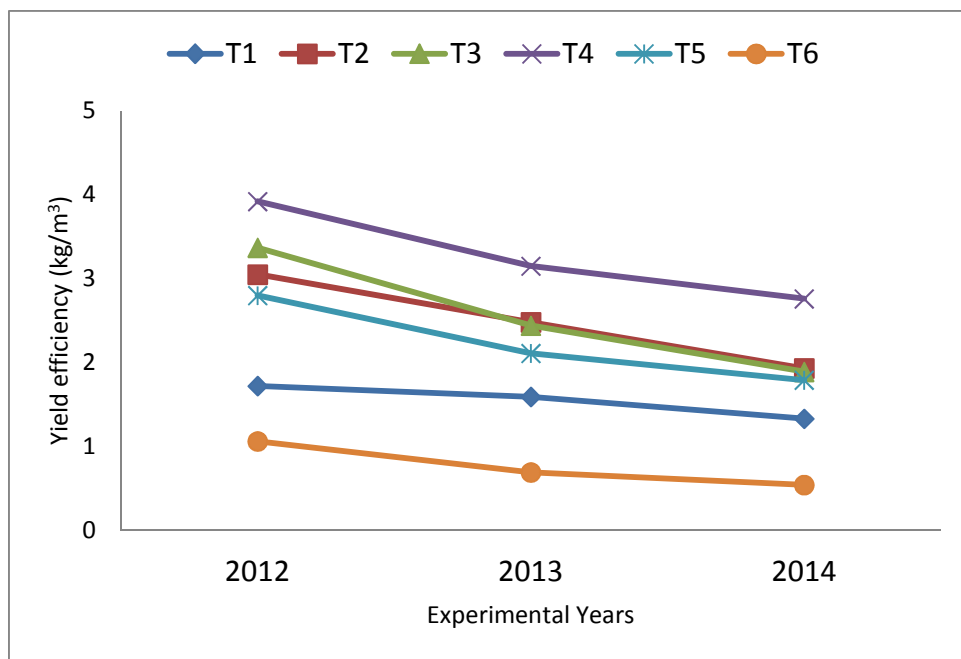


Figure 4. Yield efficiency (kg/m³) of Mandarin as influenced by interated nutrient supply

T₁= 100% Recommended Dose(RD) of nutrients as per STB (Soil test basis) from Chemical fertilizer, T₂ = 125% RD of nutrients as per STB from Chemical fertilizer, T₃ = 80% RD of nutrients from Chemical fertilizer + 20% from Cow dung, T₄= 60% RD of nutrients from Chemical fertilizer+40% from Cow dung, T₅= Existing Practice (100% RD of nutrients as per STB (Soil test basis) from Cow dung), T₆= Native nutrient (Control)

3.2. Fruit quality

The plants treated with 60% recommended nutrients as per STB from Chemical fertilizer and 40% from Cow dung (T₄) produced the heaviest fruit of voluminous size (data not presented) throughout the experimental period. Although the individual fruit weight gradually decreased, but produced larger fruits than that of the other treatments. Whereas the plants received no nutrients yielded the tiny and lightest fruit (Figure 5). There were no significant difference among the treatments regarding segments per fruit in the first year of study but in the later years on slight variations were noticed among between the treatments [BF19]. Maximum number of segments per fruit was measured counted from T₃ and T₅ in the year 2013 and T₆ in the year 2014 (Figure 6).

Seed weight also varied considerably among the treatments exhibiting the effect of integrated organic and inorganic nutrients. In 2012 highest average seed weight per fruit was measured in T₄ (60% recommended nutrients as per STB from Chemical fertilizer and 40% from Cow dung) while T₃ (80% recommended nutrients as per STB from Chemical fertilizer and 20% from Cow dung) was superior in 2013 and 2014; lowest seed weight was founded from control (Table-Figure 47).

The rind is an important quality attribute of mandarin fruit. A thick rind is in most of the cases fragile and creates difficulty to peel off the fruit. Thin peels with low average weight also facilitate higher per cent of edible portion. In all the experimental years fruits from the plants receiving only chemical nutrients (T₁ & T₂) produced fruits had with thick (data not presented) and heavy rind, whereas fruits from control plots had very much thin rind with minimum

weight. But organic nutrients (T₅) or integration of organic and inorganic nutrients (T₃ & T₄) gave the most suitable rind with medium weight which ensured the fruit quality (Figure 8).

Table 4. Influences of integrated nutrient management on qualitative fruit characteristics of mandarin orange variety BARI Mandarin-1 [BF20]

Treatments	Individual fruit weight (g)			Segments/fruits (no.)			Seed weight (g)			Rind weight (g)		
	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014
T ₁	135.2 d	135.8 e	134.0 e	10.0	9.8 b	10.0 c	2.79 e	2.76 e	2.77 e	18.4 a	18.4 b	19.0 b
T ₂	169.2 b	165.4 b	171.6 b	10.4	10.0 b	10.2 bc	2.67 c	2.67 d	2.67 d	18.4 a	19.8 a	19.8 ab
T ₃	154.4 c	152.4 d	144.6 d	10.6	11.2 a	10.4 a-c	3.63 b	3.84 a	3.83 a	17.8 ab	18.4 b	18.8 b
T ₄	182.0 a	178.2 a	173.8 a	10.8	10.0 b	11.0 ab	3.82 a	3.48 b	3.57 b	17.7 b	19.5 a	20.3 a
T ₅	167.2 b	160.8 c	161.8 c	10.4	11.2 a	10.2 bc	2.69 e	2.70 d	2.63 d	14.4 c	15.2 c	16.7 c
T ₆	108.0 e	100.2 f	98.40 f	10.6	10.4 ab	11.2 a	2.23 d	2.19 e	2.17 e	11.2 d	12.2 d	11.6 d
LSD	3.27	2.08	2.18	1.77	0.765	0.831	0.14	0.056	0.06	0.57	0.99	1.10
CV%	1.19	0.78	0.82	9.43	5.56	7.25	2.69	1.12	1.07	3.20	3.19	3.46

In a column means followed by common letters are not significantly different from each other at 5% level of probability by DMRT.

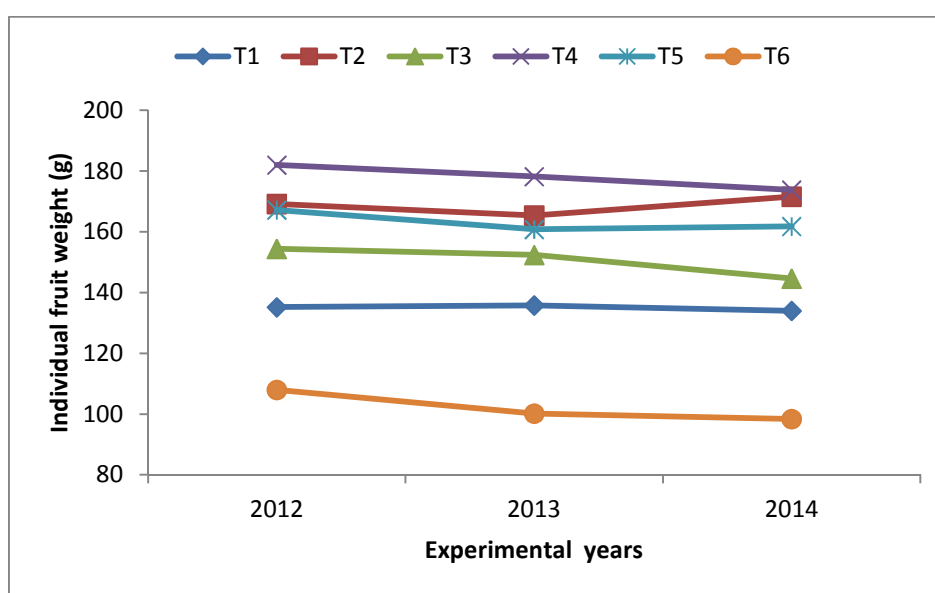


Figure 5. Influences of integrated nutrient management on individual fruit weight of mandarin orange

T₁= 100% Recommended Dose(RD) of nutrients as per STB (Soil test basis) from Chemical fertilizer, T₂ = 125% RD of nutrients as per STB from Chemical fertilizer, T₃ = 80% RD of nutrients from Chemical fertilizer + 20% from Cow dung, T₄= 60% RD of nutrients from Chemical fertilizer+40% from Cow dung, T₅= Existing Practice (100% RD of nutrients as per STB (Soil test basis) from Cow dung), T₆= Native nutrient (Control)

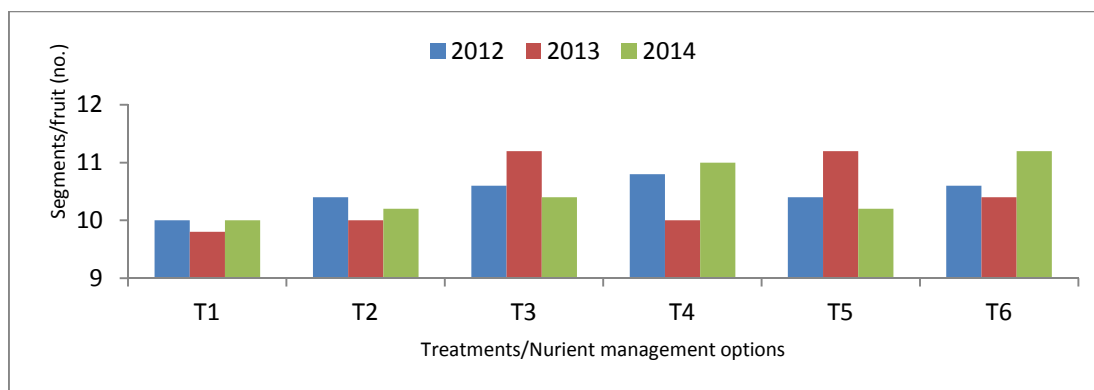


Figure 6. Influences of integrated nutrient management on segments/fruit of mandarin orange

T₁= 100% Recommended Dose(RD) of nutrients as per STB (Soil test basis) from Chemical fertilizer, T₂ = 125% RD of nutrients as per STB from Chemical fertilizer, T₃ = 80% RD of nutrients from Chemical fertilizer + 20% from Cow dung, T₄= 60% RD of nutrients from Chemical fertilizer+40% from Cow dung, T₅= Existing Practice (100% RD of nutrients as per STB (Soil test basis) from Cow dung), T₆= Native nutrient (Control)

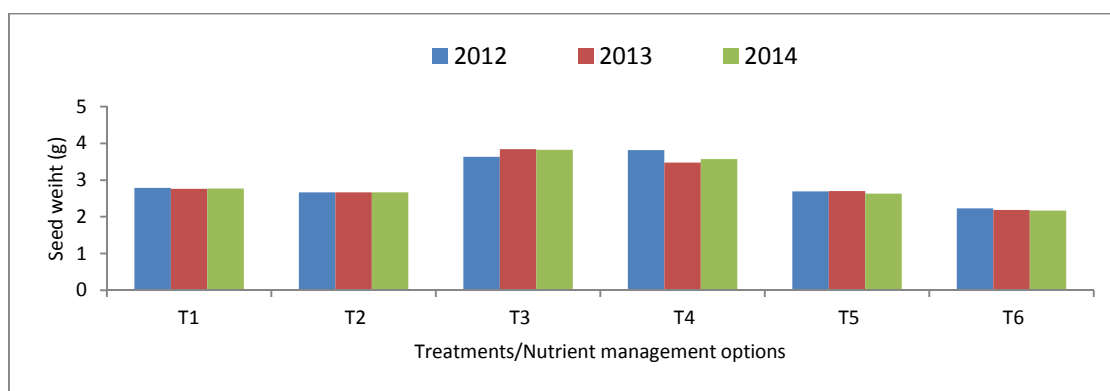


Figure 7. Influences of integrated nutrient management on seed weight of mandarin orange

T₁= 100% Recommended Dose(RD) of nutrients as per STB (Soil test basis) from Chemical fertilizer, T₂ = 125% RD of nutrients as per STB from Chemical fertilizer, T₃ = 80% RD of nutrients from Chemical fertilizer + 20% from Cow dung, T₄= 60% RD of nutrients from Chemical fertilizer+40% from Cow dung, T₅= Existing Practice (100% RD of nutrients as per STB (Soil test basis) from Cow dung), T₆= Native nutrient (Control)

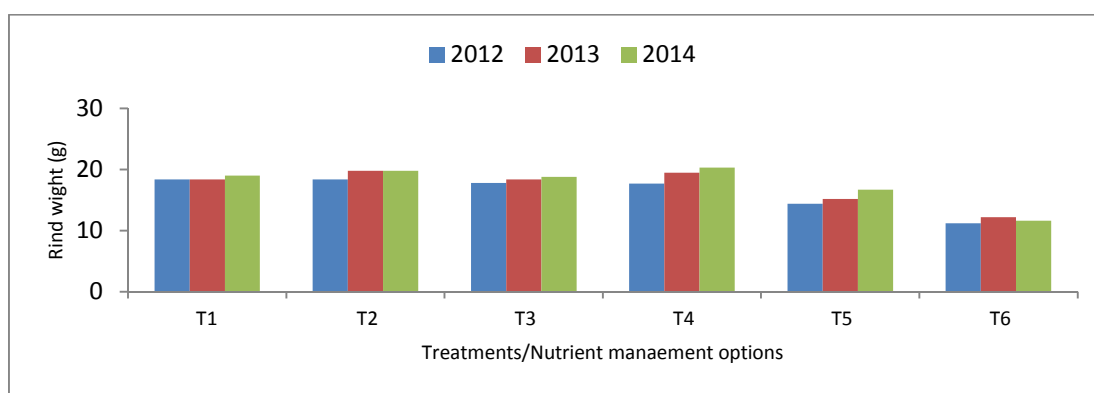


Figure 8. Influences of integrated nutrient management on rind weight of mandarin orange

T₁= 100% Recommended Dose(RD) of nutrients as per STB (Soil test basis) from Chemical fertilizer, T₂ = 125% RD of nutrients as per STB from Chemical fertilizer, T₃ = 80% RD of nutrients from Chemical fertilizer + 20% from Cow dung, T₄= 60% RD of nutrients from Chemical fertilizer+40% from Cow dung, T₅= Existing Practice (100% RD of nutrients as per STB (Soil test basis) from Cow dung), T₆= Native nutrient (Control)

Juice percentage of fruits increased compared to the control in all the test years, from trees received nutrients from both organic and inorganic sources (Table 5 Figure 9). In 2012 plants received 60% recommended nutrients as per STB from Chemical fertilizer and 40% from Cow dung (T₄) produced most juicy fruits where as in 2013 and 2014 plants received 80% recommended nutrient as per STB from Chemical fertilizer and 20% from Cow dung (T₃) produced most juicy fruits revealed the effects of integrated nutrient on the juice content. Juice total soluble solids (TSS) content was supreme from the fruits produced on plants received 80% recommended nutrients as per STB from Chemical fertilizer and 20% from Cow dung (T₃) in all the years of study and significantly differed between the other nutrient management options whereas lowest soluble solids were achieved from the fruits on trees grown without nutrients (Figure 10).

Titrateable acidity (TA) is also an important factor for measuring the fruit quality. The organoleptic sourness of fruit increased with the increasing TA although TSS of that particular fruit is high. The study unfolded the effect of integrated nutrient management regarding percent TA and maturity index badly. In all the experimental years plants received 80% recommended nutrients as per STB from Chemical fertilizer and 20% from Cow dung (T₃) contained the lowest percent of TA and hence produced highest maturity index. Mandarin plants received 60% recommended nutrients as per STB from Chemical fertilizer and 40% from Cow dung (T₄) was also better and ranks second among the treatments in respect to maturity index having second lowest percent TA while worst maturity index along with maximum percent TA was found in the fruits of plants received no supplemented nutrients (T₆) irrespective of years (Table 5 Figure 11).

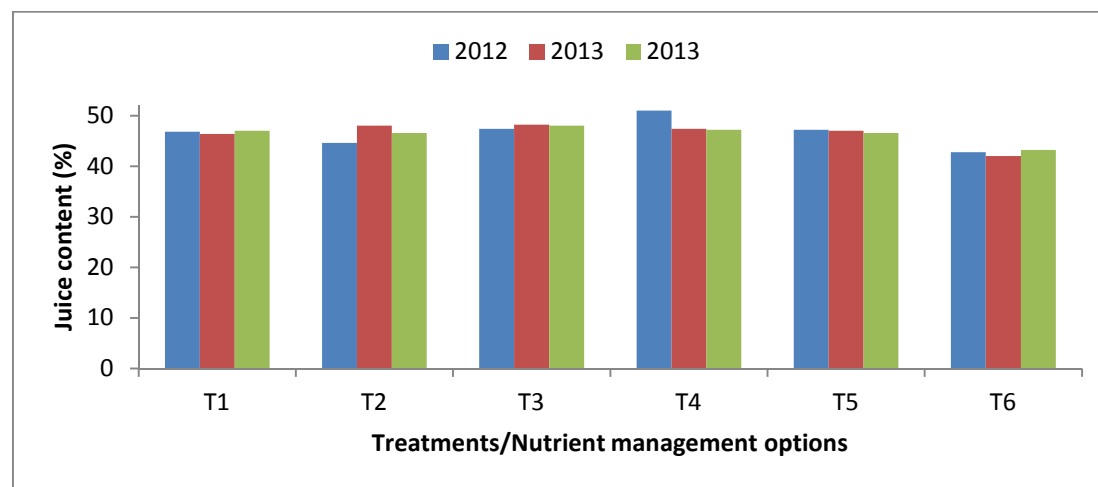
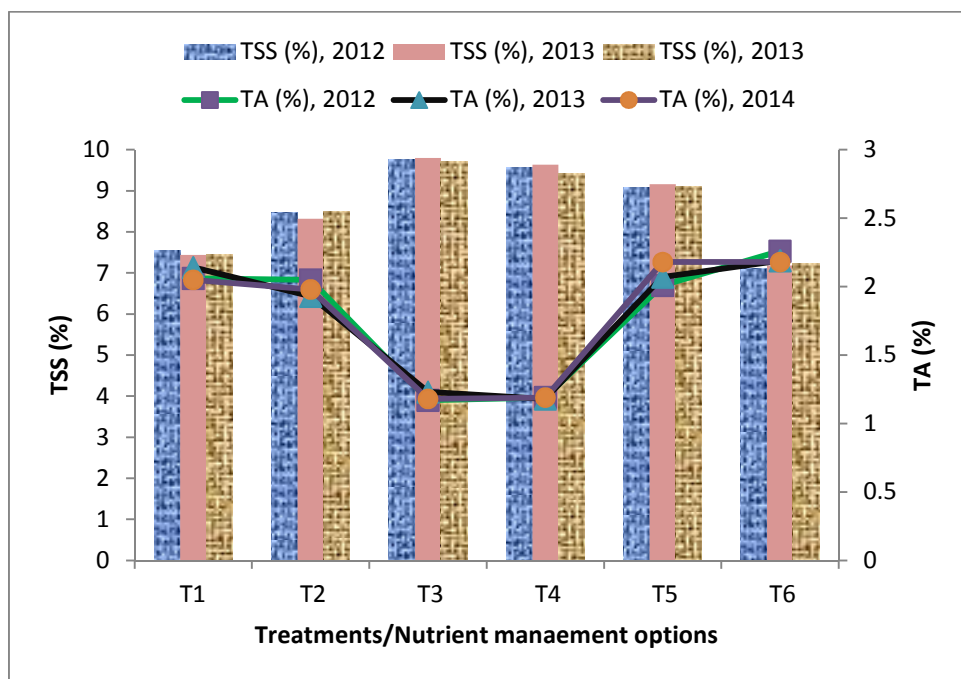


Figure 9. Juice content (%) as influenced by different integrated nutrient management options

T₁= 100% Recommended Dose(RD) of nutrients as per STB (Soil test basis) from Chemical fertilizer, T₂ = 125% RD of nutrients as per STB from Chemical fertilizer, T₃ = 80% RD of nutrients from Chemical fertilizer + 20% from Cow dung, T₄= 60% RD of nutrients from Chemical fertilizer+40% from Cow dung, T₅= Existing Practice (100% RD of nutrients as per STB (Soil test basis) from Cow dung), T₆= Native nutrient (Control)

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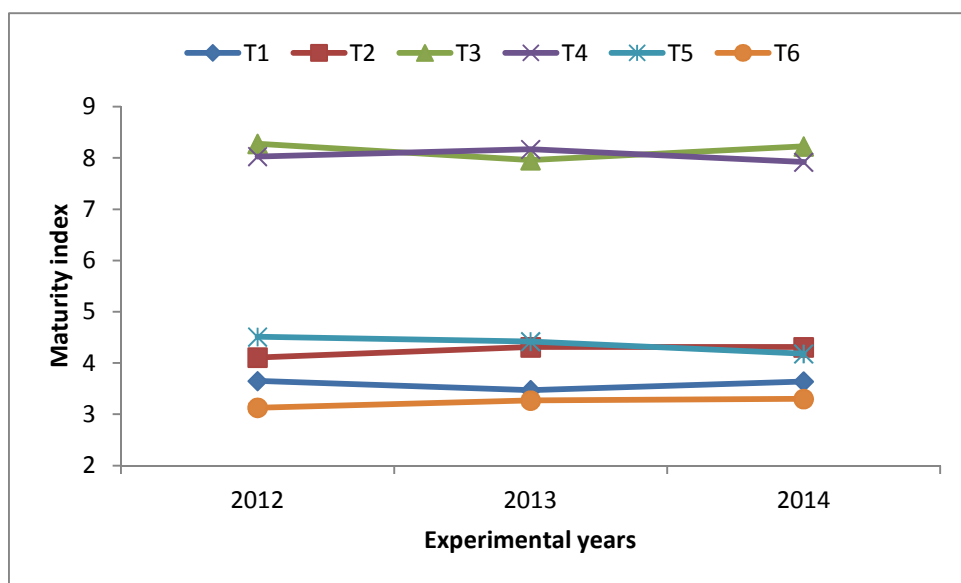
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Figure 10. TSS (%) and TA (%) as influenced by different integrated nutrient management options

TSS, total soluble solids; TA, titratable acidity

T₁= 100% Recommended Dose(RD) of nutrients as per STB (Soil test basis) from Chemical fertilizer, T₂ = 125% RD of nutrients as per STB from Chemical fertilizer, T₃ = 80% RD of nutrients from Chemical fertilizer + 20% from Cow dung, T₄= 60% RD of nutrients from Chemical fertilizer+40% from Cow dung, T₅= Existing Practice (100% RD of nutrients as per STB (Soil test basis) from Cow dung), T₆= Native nutrient (Control)



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Figure 11. Maturity index as influenced by different integrated nutrient management options

MI, Maturity Index (TSS/TA)

T₁= 100% Recommended Dose(RD) of nutrients as per STB (Soil test basis) from Chemical fertilizer, T₂ = 125% RD of nutrients as per STB from Chemical fertilizer, T₃ = 80% RD of nutrients from Chemical fertilizer + 20% from Cow

dung, T₄= 60% RD of nutrients from Chemical fertilizer+40% from Cow dung, T₅= Existing Practice (100% RD of nutrients as per STB (Soil test basis) from Cow dung), T₆= Native nutrient (Control)

Table 5. Quantitative fruit characters as influenced by different integrated nutrient management options

Treatments	JC (%)			TSS (%)			TA(%)			MI		
	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014
T ₁	46.80 b	46.40 b	47.00 ab	7.54 e	7.44 e	7.46 e	2.06 b	2.14 b	2.05 b	3.65 e	3.47 e	3.64 d
T ₂	44.60 c	48.00 ab	46.60 b	8.46 d	8.32 d	8.50 d	2.05 b	1.93 d	1.98 c	4.11 d	4.31 d	4.31 c
T ₃	47.40 b	48.20 a	48.00 a	9.76 a	9.80 a	9.72 a	1.17 d	1.23 f	1.18 d	8.28 a	7.96 a	8.23 a
T ₄	51.00 a	47.40 ab	47.20 ab	9.56 b	9.64 b	9.42 b	1.19 c	1.18 e	1.19 c	5.09 b	5.15 b	4.77 b
T ₅	47.20 b	47.00 ab	46.60 b	9.08 c	9.16 c	9.12 c	2.01 b	2.07 c	2.18 a	4.51 c	4.42 c	4.18 c
T ₆	42.80 c	42.00 c	43.20 c	7.10 f	7.18 f	7.22 f	2.26 a	2.19 a	2.18 a	3.13 f	3.27 f	3.30 e
LSD	1.84	1.53	1.22	0.15	0.14	0.13	0.05	0.02	0.018	0.18	0.09	0.16
CV%	2.20	1.83	1.99	1.00	0.90	0.87	1.78	1.10	0.87	2.07	1.14	1.89

JC, juice content; TSS, total soluble solids; TA, titratable acidity; MI, Maturity Index (TSS/TA); In a column means followed by common letters are not significantly different from each other at 5 % level of probability by DMRT.

T₁= 100% Recommended Dose(RD) of nutrients as per STB (Soil test basis) from Chemical fertilizer, T₂ = 125% RD of nutrients as per STB from Chemical fertilizer, T₃ = 80% RD of nutrients from Chemical fertilizer + 20% from Cow dung, T₄= 60% RD of nutrients from Chemical fertilizer+40% from Cow dung, T₅= Existing Practice (100% RD of nutrients as per STB (Soil test basis) from Cow dung), T₆= Native nutrient (Control)

3.3. Partial budget and marginal rate of return (MRR)

The economic analysis of mandarin oranges production through integrated nutrient management was performed by the partial budget process is illustrated in Tables 6 and 7. Through the study, highest net return per plant of Tk. (Taka-currency of Bangladesh) 698.8, Tk. 760.0 and Tk. 816.0 was obtained by the year 2012, 2013 and 2014 respectively from the treatment T₄ (60% recommended nutrients as per STB from Chemical fertilizer and 40% from Cow dung) while a lowest net benefit of Tk. 417.0, Tk. 484.2 and Tk. 539.4 were obtained from plants received no fertilizer (T₆) in the year 2012, 2013 and 2014 respectively.

However, the dominance analysis showed, one of the six treatments is unacceptable for investment for the growers because of the others options having higher net benefits at comparatively low variable cost (cost dominated) irrespective of years, thus that treatment was departed for the marginal rate of return (MRR) calculation.

Table 7. Partial budget and dominance analysis for different integrated nutrient management options for mandarin orange production during 2012-2014

Treatments	Gross return (Tk./plant)			Variable cost (Tk./plant)			Net return (Tk./plant)			Remarks		
	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014
T ₁	321.6	393.6	432	63	63	63	258.6	330.6	369	CU	CU	CU
T ₂	460.8	530.4	552	66	66	66	394.8	464.4	486	CU	CU	CU
T ₃	597.0	640.8	686.4	115	115	115	482	525.8	571.4	CU	CU	CU
T ₄	698.8	760.0	816.0	117	117	117	581.8	643	699	CU	CU	CU
T ₅	444.0	511.2	566.4	67	67	67	377	444.2	499.4	CD	CD	CD
T ₆	224.1	227.2	213.6	0	0	0	224.1	227.2	213.6	CU	CU	CU

T₁= 100% Recommended Dose(RD) of nutrients as per STB (Soil test basis) from Chemical fertilizer, T₂ = 125% RD of nutrients as per STB from Chemical fertilizer, T₃ = 80% RD of nutrients from Chemical fertilizer + 20% from Cow dung, T₄= 60% RD of nutrients from Chemical fertilizer+40% from Cow dung, T₅= Existing Practice (100% RD of nutrients as per STB (Soil test basis) from Cow dung), T₆= Native nutrient (Control), Tk-Taka (Currency of Bangladesh), CU-Cost un-dominated, CD-Cost dominated

The MRR analysis showed that the highest marginal rate of return (MRR) was obtained from the treatment T₄ (60% recommended nutrients as per STB from Chemical fertilizer and 40% from Cow dung) at par with T₂ (125% recommended nutrients as per STB from Chemical fertilizer). MRR values for changing from the control (no fertilizer) to chemical fertilizer were

155%, 264% and 347% while changing from chemical fertilizer to integration of organic and inorganic nutrients were 278%, 225% and 274% in 2012, 2013 and 2014 respectively (Table 7). Hence, application of 60% RD of nutrients as per STB from Chemical fertilizer and 40% from Cow dung for mandarin orange plant would be economically acceptable for the growers.

Table 73. Marginal analysis of un-dominated integrated nutrient management options of mandarin orange production during 2012-2014

Treatments	Net return (Tk./plant)			Variable cost (Tk./plant)			Marginal increase in net return (Tk./plant)			Marginal increase in variable cost (Tk./plant)			Marginal rate of return (%)		
	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014
T ₄	698.8	760.0	816.0	117	117	117	101.8	119.2	129.6	2	2	2	5090	5960	6480
T ₃	597.0	640.8	686.4	115	115	115	136.2	110.4	134.4	49	49	49	278	225	274
T ₂	460.8	530.4	552.0	66	66	66	139.2	136.8	120	3	3	3	4640	4560	4000
T ₁	321.6	393.6	432.0	63	63	63	97.5	166.4	218.4	63	63	63	155	264	347
T ₆	224.1	227.2	213.6	0	0	0	-	-	-	-	-	-	-	-	-

T₁= 100% Recommended Dose(RD) of nutrients as per STB (Soil test basis) from Chemical fertilizer, T₂ = 125% RD of nutrients as per STB from Chemical fertilizer, T₃ = 80% RD of nutrients from Chemical fertilizer + 20% from Cow dung, T₄= 60% RD of nutrients from Chemical fertilizer+40% from Cow dung, T₅= Existing Practice (100% RD of nutrients as per STB (Soil test basis) from Cow dung), T₆= Native nutrient (Control), Tk-Taka (Currency of Bangladesh)

4. DISCUSSION

A significant increase in terms of growth, yield and profitability of mandarin production due to dissimilar integrated nutrient management pointed out that available plant nutrient status of soil was not satisfactory. Application integration of organic and inorganic nutrients perhaps assisted sustaining productiveness that aid to better growth and development of plants with higher fruit set and weight resulted in elevated yield corroborates with few other researchers [21]. who stated about the poor status of available nutrients of lots of agricultural soils of world which may conserve with maximum yield through proper nutrient supply. Few Some scientists observed that citrus trees may not grow suitably without inorganic nutrients proper Nitrogen (N), Phosphorus (P) and potassium (K) supply [22]. Moreover, organic matter permits better aeration, enhances the absorption and release of nutrients, and makes the soil less susceptible to leaching and erosion [23, 24]. that also supports the present result. In many cases farmers may use only organic or inorganic fertilizers which lead to poor growth. In Shaanxi province of China about 20-80% of orchards received no fertilizers and about 80% of orchards received no manures resulted poor yield which was found by us as well. [BF21]

Maximum height and volume of plants were due to found with application of 60% recommended nutrients as per STB from Chemical fertilizer and 40% from Cow dung (T₄) revealed that integration of inorganic and organic nutrients to soil improves soil physical property, microbial activity and availability of essential nutrients of soil. [BF22] The increase in plant height and girth might be due to improvement of the physical properties of soil, which was also evidenced with the study of Kumar et al. [25]. Some scientists also affirmed about the application of inorganic fertilizers and organic manures to avail organic carbon, N, P and K status along with microbial biomass and dehydrogenase activity helping in vegetative growth in apple trees [26], corroborates with the findings of present study. [BF23]

Plant growth characters significantly affect the yield contributing characters and yield. [BF24] As the growth parameters boosted up, there was an opportunity for accumulating more food and dry matter that helps in the amplified area excellently pursued for gathering of dry matter grants larger opportunity for higher production. In the present experiment plants that received nutrients from both organic and inorganic sources exhibited more number of fruits in each per plant, along with aided higher yield per plant and yield efficiency. This might be

due to faster vegetative growth ~~that responsible for~~ progress in photosynthesis rate and improvement of the photosynthates translocation ~~from source to sink results in ultimate yield and yield efficiency in all the study years which are in~~ This result is in conformity with other researchers in banana [27]. ~~Some stated about elevated yield by using chemical fertilizers along with organic soil amendments that enriched the soil fertility [9]prop up the our result. In Contrary contrary~~ Monga et al. found application of chemical fertilizer for NPK plant nutrients were found to be best for sustainable fruit yield of kinnow mandarin cv. Kinnow by Monga et al. [28], but our result doesn't corroborates with them. ~~where a highest yield was using $N_{300}P_{125}K_{225}Mg_{60}$ g/plant along with 20 kg cow dung/plant in case of khasi mandarin by Nasreen et al. [2] that matches the current results. Significantly positive correlation was found from the relationship between plant volume (m^3) and yield efficiency ($kg/plant/m^3$). [BF25]~~

~~For achieving high efficiency and lofty fruit quality orchard management should be done by proper nutrient organization [BF26]. In this immediate experiment varying Integrated nutrient management affects the fruit quality respect to . There were significant variations among the treatments in terms of individual fruit weight in all the experimental year. Although the, number of segments per fruit was not significant at all but, seed weight and rind weight per fruit varied noteworthy. For quality fruit despite of macronutrients other micronutrients are also responsible [BF27] that are mainly supplied by organic manure facilitates carbon buildup and sustained release of available nutrients to the plants that also confirmed by others [29, 30, 31]. Application of different nutrients through inorganic fertilizers, manures and biofertilizers increased the soil nitrogen, phosphorus and potassium contents [32, 33] improve fruit quality [34, 35, 36, 37] which is rather sensitive to K availability [38] and if the availability of K increased, there were chances to found large fruits with tends to be bigger with thick and harsh peel whereas smaller fruits with thin peel resulted from K unavailability which affirmed this study. Greater physical Superior fruit quality was also for the reality fact that, combined application of organic and inorganic manure enhance soil nutrient availability of soil was enhanced by organic manures and fertilizers triggers the potential of plants to uptake considerable amount of solute from rhizosphere that are in accordance with also supported by other scientists [39, 40] in sapota [BF28]. Organic manures and biofertilizers also have direct role in nitrogen fixation, production of phytohormones and increased nutrients uptake hence fruit quality improvement. These observations corroborates with the findings of others Madhavi et al. [41] in mango Alva and Paramasivam and [42] in sapota.~~

Significant difference also found in terms of juice percent, juice total soluble solids, titratable acidity and maturity index also. ~~Balanced nutrient helped in reducing juice acidity thus increasing the fruit taste [BF29].~~ Similar findings have been reported by other researchers [25, 42, 43, 44], ascribed to uptake of more nitrogen and potassium in plant system increased total sugars in fruit due to accumulation of more photosynthates [45]. Alva et al. found Uptake uptake of magnesium, calcium, and ammonium N is prohibited by high K availability in the soil deteriorate juice properties regards titratable acidity [38] and maximum total soluble solid (%) from fruits grown on those trees received $N_{300}P_{125}K_{225}Mg_{30}$ g/plant/year [2] which supports the present findings. Fertilizing also positively influence in quality of citrus fruit [46, 47, 48] and the greatest effect from nutrition in the quality of the fruit, is related to the supply of nitrogen and potassium; the former (N), tends to reduce the size of the fruit and increase the quantity of juice, soluble solids and acidity. However, organic fertilizer may give better result terms of yield, although does not interfere with the size or quality of the fruits [49] that does not keep in with the present study.

~~For the farmer, an economic option may differ depending on the increased cost of inputs and the benefits derived from the output.~~ The greatest challenge for farmers is to gain a product at a price that allows a profit which will also fulfills the consumers' requirement. Use of different levels of integrated nutrient management affects ~~on~~ the economic return. Use of

sole organic matter was cost dominated in the present study while integrated use of organic and inorganic nutrients showed the best marginal rate of return. This results are in accordance with Nasreen et al. [2]. Erosion and organic matter reduction of soil may increases bulk density affects soil quality lead to lower yields and/or higher costs of production [49] thus for costs reduction along with maintaining soil physical, chemical and biological properties producers should use of organic nutrient [50] which is homologous with the present findings. Therefore integrated application of organic manure and inorganic fertilizers may be a better option for enhancing yield, quality and productivity of mandarin in humid tropical region of Bangladesh.

5. CONCLUSION

Considering all the parameters in three years' of study it was revealed that 60% recommended nutrients as per STB from Chemical fertilizer and 40% from Cow dung may be recommended as the best integrated nutrient dose for achieving higher yield and better fruit quality of mandarin production.

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