

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 at Citrus Research Station, Bangladesh Agricultural Research Institute (BARI), Jaintiapur, Sylhet, Bangladesh in three consecutive years viz. 2012, 2013 and 2014. Mandarin variety BARI Mandarin-1 was used as the planting material. The experiment consists of six treatments laid out in a randomized complete block design fashion. 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 maximum from the plants receiving 60% of required nutrients as per soil test basis from chemical fertilizer and 40% from Cow dung with the highest marginal rate of return, while less productivity obtained when the plants were grown under native nutrient status of soil that retains less number of fruit of smaller size and lower weight resulted in lower yield. However, use of chemical fertilizers solely or even in higher dose than recommendation didn't give a significant variation. Hence, application of 60% recommended dose of nutrients as per soil test basis from Chemical fertilizer and 40% from cow dung may be a wise and economic option for mandarin orange var. BARI Manderin-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 soil conservation as well as maximizing crop productivity, as soil health problem is exacerbating for targeting to accelerate food production for escalating population. Mandarin (*Citrus reticulata* Blanco) is a popular minor fruit of Bangladesh. It is tasty fruit having nutritional and medicinal value [1] also rich in vitamin A, B and C (40 mg/100 g juice) with recognized immense economic importance.

In north eastern hilly region of Bangladesh is characterized with small hills and hillocks, wet summer and dry winter 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.

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) 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 [2, 3, 4, 5]. Mandarin yield can be increased in the course of applying organic amendments to soil with different chemical fertilizers [6]. Significant growth, yield and quality of citrus fruit were found with definite role of N, P, Mg, Zn, and B in India [7]. Thus, various fruit crops found to respond positively to organic manures and inorganic fertilizers (the cheap available nutrient source) on growth, yield and quality [8]. Hence, integrated nutrient management with organic and inorganic fertilizer towards significant growth, sustainable yield, quality and profitability is an urgent need.

But, very few systematic works on the nutritional requirement of mandarin in the hilly regions has been carried out. Therefore, reclaiming soil health through integrated nutrient management is an urgent need for sustainable mandarin production, yield and better quality fruits also to leave dependency on import. Keeping this view in mind this experiment was undertaken to boost the yield and profitability of mandarin orange cultivation through integrated nutrient management.

2. MATERIAL AND METHODS

2.1. Field trial

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 was 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]. The physico-chemical properties of the soil were analyzed before every experimental year for recommended fertilizer dose 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 experiment consists of six treatments viz. T₁= 100% Recommended Dose (RD) as per STB (Soil test basis), T₂ = 125% RD as per STB, T₃ = 80% RD from Chemical fertilizer + 20% from Cow dung, T₄= 60% RD from Chemical fertilizer 40% from Cow dung, T₅= Existing Practice (Cow dung), T₆= Native nutrient (Control).

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

Parameters	Experimental year					
	2012	Remarks	2013	Remarks	2014	Remarks
pH	4.8	Very acidic	5.8	Acidic	5.4	Acidic
OM (%)	1.67	Low	1.8	Low	1.85	Low
N (% Total)	0.141	Low	0.152	Low	0.155	Low
P (µg/ml)	18.1	Optimum	19.1	Optimum	19.5	Optimum
K (meq/100ml)	0.07	Low	0.08	Low	0.08	Low
S (µg/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 (µg/ml)	0.26	Medium	0.25	Medium	0.25	Medium
Zn (µg/ml)	1.25	Optimum	1.19	Optimum	1.18	Optimum
Cu (µg/ml)	0.45	Optimum	0.44	Optimum	0.41	Optimum
Fe (µg/ml)	12.2	Very high	12.2	Very high	12.1	Very high
Mn (µg/ml)	2.2	Optimum	2.0	Optimum		Optimum

2.2. Cultural management

Fertilizer was applied as per treatment; Dolomite (agricultural lime) 4 kg/decimal was applied only in the first year of experiment for managing soil pH. 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. Nutrients N, P, K and S were applied to the plant as urea, triple super phosphate, muriate of potash, and gypsum respectively. 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 imidachloprid. 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.

2.3. Growth, yield attributes and yield measurement

Data were recorded on growth parameters viz. percent growth in plant height, plant volume (m^3), fruits per plant, yield per plant (kg) and yield efficiency kg per plant per m^3 . Following through minor amendment canopy 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 [10]. Yield (kg/plant) was recorded on every commercial harvest. Yield efficiency was computed from the relationship between fruit yield (kg/plant) and canopy volume (m^3). The relationship between yield efficiency and tree volume was analyzed by a regression model [11].

2.4. 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 weigh (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 [12]. Total soluble solids content (TSS) was measured with the help of refracto-meter and corrected with temperature factor [13]. By titrating 10 ml juice with 1% NaOH, titratable acidity (TA) was measured [12]. Maturation index (MI), calculated by the ratio of TSS:TA [14].

2.5 Economic analysis

Profitability of mandarin production was estimated using partial budget [1]. Partial budget was investigated determining the most cost-effectively 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 [15]. 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 costs that vary were 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 [16].

After identification of the dominated treatments only undominated treatments were taken for, marginal analysis in a sequential way, starts from one treatment with the highest costs that vary to the next. This is to show the decrease of the net benefit from one option to another with cost. Marginal rate of return (%) was calculated for each couple of ranked undominated treatments, a. The return per unit of investment in any nutrient management option illustrated in percentage denotes the percent MRR between any undominated treatments pair. Therefore, marginal rate of return was measured by the relationship between the change in net benefit and change in total cost that varies expressed to percentage using the following formula [16]:

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

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 learning fresh skills or purchasing new field equipments. Thus, any treatment that gave MRR exceeding 50% is considered admirable for farmers' investment [15, 16, 17].

2.6 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 was performed for mean separations of the studied parameters and interpretation of results [18].

3. RESULTS AND DISCUSSION

3.1. Height and plant volume

The height and plant volume of mandarin variety BARI Mandarin-1 was clearly affected by the nutrient management options (Table 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 canopy volume, which was also followed in the second year of the study (212.8 cm height and 3.58 m³ plant volume respectively). But in the third year of study more vigorosity (235.0 cm height and 4.36 m³ plant 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.

175 **Table 2. Effect of integrated nutrient supply on height and plant volume of nth and**
176 **yield of mandarin oranges**

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

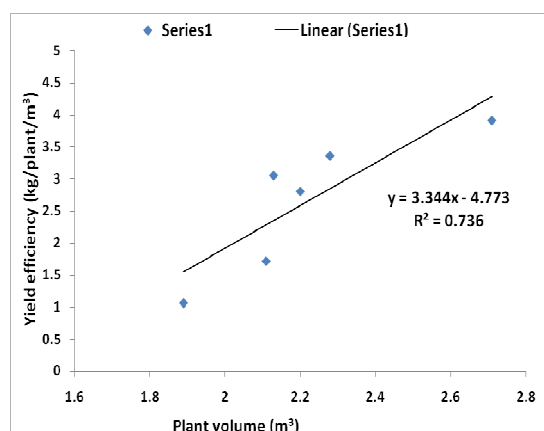
177 In a column means followed by common letters are not significantly different from each other at 5 & 1 % level of
178 probability by DMRT.

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180 T₁= 100% RD as per STB, T₂ = 125% RD as per STB, T₃= 80% RD as per STB from Chemical fertilizer + 20% from
181 Cow dung. T₄= 60% RD as per STB from Chemical fertilizer + 40% from Cow dung, T₅= Existing Practice CD, T₆=
182 Control

183 3.2. Yield

184 Effects of integrated nutrient supply showed significant variations on yield characters also. In
185 all year of the experiment less productivity was obtained from the control treatment where
186 the plants grown under native nutrient status of soil (T₆). These plants retained less number
187 of fruit with comparatively smaller sized fruit (data not presented) of lower individual fruit
188 weight resulting small yield per plant and yield efficiency (Table 3). Throughout the
189 experiment maximum number of fruit was carried by the plants received 60% recommended
190 nutrient as per STB from Chemical fertilizer + 40% from Cow dung (T₄) demonstrating the
191 influence of integrated management of organic and inorganic nutrients followed by the plants
192 received 60% recommended nutrient as per STB from Chemical fertilizer + 40% from Cow
193 dung (T₃). However, use of chemical fertilizers solely (T₁) or even in higher dose than
194 recommendation (T₂) didn't give a significant variation respect to fruits per plant, yield and
195 yield efficiency.
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198 A significant positive linear relationship between yield efficiency and plant volume (Fig. 1-a, b
199 and c) confirmed the superior performance of T₄ (60% recommended nutrient as per STB
200 from Chemical fertilizer + 40% from Cow dung) for producing mandarin orange BARI
201 Mandarin-1, differing from the least productive T₆ (Native nutrient) in all the experimental
202 years (2012, 2013 and 2014).
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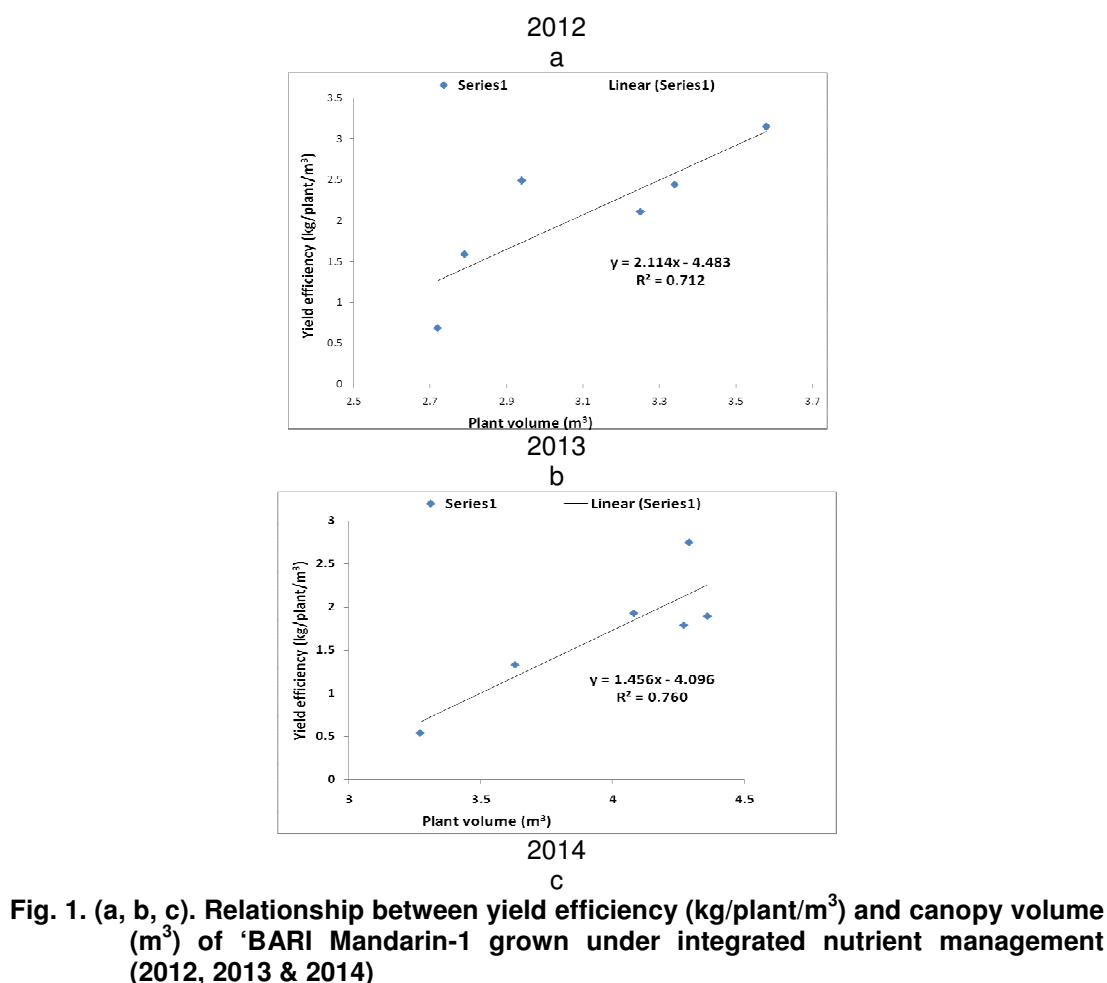


Table 3. Yield characteristics of BARI Kamala-1 as influenced by different levels and forms of nutrient application

Treatments	Fruits/plant (no.)			Weight of fruits/plant (kg)			Yield efficiency (Kg/m³)		
	2012	2013	2014	2012	2013	2014	2012	2013	2014
T ₁	26.80 d	32.80 d	36.00 d	3.62d	4.45 d	4.82 d	1.72 d	1.59 d	1.33 d
T ₂	38.40 c	44.20 c	46.00 c	6.49 c	7.31 c	7.89 bc	3.05 cd	2.48 b	1.93 b
T ₃	49.75 b	53.40 b	57.20 b	7.68 b	8.14 b	8.27 b	3.37 b	2.44 b	1.89 b
T ₄	58.23 a	63.33 a	68.00 a	10.60 a	11.29 a	11.82 a	3.92 a	3.15 a	2.76 a
T ₅	37.00 c	42.60 c	47.20 c	6.18 c	6.85 c	7.63 c	2.80 d	2.11 c	1.79 c
T ₆	18.67 e	18.93 e	17.80 e	2.02 e	1.89 e	1.75 e	1.06 e	0.69 e	0.54 e
LSD	2.48	3.53	2.52	0.40	0.57	0.40	0.44	0.63	0.45
CV%	3.62	4.62	3.09	3.67	4.79	3.21	3.67	4.79	3.21

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

T₁= 100% RD as per STB, T₂ = 125% RD as per STB, T₃= 80% RD as per STB from Chemical fertilizer + 20% from Cow dung. T₄= 60% RD as per STB from Chemical fertilizer + 40% from Cow dung, T₅= Existing Practice CD, T₆= Control

3.2. Fruit quality

The plants treated with 60% RD as per STB from Chemical fertilizer + 40% from Cow dung (T₄) produced the heaviest fruit of largest size (data not presented) throughout the experimental period. Although the individual fruit weight gradually decreased, T₄ produced significantly superior fruit than the other treatments. Whereas the plants received no nutrients produced the smallest and lightest fruit. There were no significant difference among the treatments regards to segments per fruit in the first year of study but later years slight variations were noticed among the treatments. The maximum number of segments per fruit was measured from T₃ and T₅ in the year 2013 and T₆ in the year 2014. Seed weight also varied significantly among the treatments remaining the effect of integrated effect of organic and inorganic fertilizers in growing mandarin oranges. In 2012 highest average seed weight per fruit was in T₄ (60% RD as per STB from Chemical fertilizer + 40% from Cow dung) while T₃ (80% RD as per STB from Chemical fertilizer + 20% from Cow dung) was superior with utmost seed weight per fruit in rest of the years; lowest seed weight was found from control (Table 4). The rind is an important factor for the quality of mandarin fruit. A thick rind are 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) had thick (data not presented) and heavy rind, whereas control plots had very much thin rind with minimum weight. But farmers' existing practices (T₅) or integration of organic and inorganic nutrients (T₃ & T₄) gave the most suitable rind with medium weight ensured the fruit quality.

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

Treatments	Individual fruit weight (g)			Segments/fruits (no.)			Seed weight (g)			Skin 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 c	2.76 c	2.77 c	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 c	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.

T₁= 100% RD as per STB, T₂ = 125% RD as per STB, T₃= 80% RD as per STB from Chemical fertilizer + 20% from Cow dung, T₄= 60% RD as per STB from Chemical fertilizer + 40% from Cow dung, T₅= Existing Practice CD, T₆= Control

The effect of different nutrients treatments was also significant on Juice content (JC), Total soluble solids (TSS), titratable acidity (TA) and maturity index (MI) of mandarin orange in all the test years (Table 5). Juice percentage increased from the control treatment in all the test years, inside fruits from trees received nutrients from organic and inorganic sources. In 2012 fruits produced from the plants received 60% of nutrients from RD as per STB from Chemical fertilizer and 40% from Cow dung (T₄) were most juicy where as plants received 80% of nutrients from RD as per STB from Chemical fertilizer and 20% from Cow dung (T₃) produced the fruits contained maximum juice in 2013 and 2014 revealed that the effects of integrated nutrient on the juice content of the fruit. Juice total soluble solids (TSS) content was maximum from fruits produced on plants received 80% of nutrients from RD as per STB from Chemical fertilizer and 20% from Cow dung (T₃) on average in all the years of study and varied significantly between the other nutrient management options whereas lowest soluble solids were from the fruits on trees grown without nutrients.

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. From the study it was discovered that integrated nutrient management options affects percent TA and maturity index badly. In all the experimental years plants received 80% of nutrients from RD as per STB from Chemical fertilizer and 20% from Cow dung (T_3) contained the lowest percent of TA and hence produced highest maturity index. Mandarin plants received 60% of nutrients from RD as per STB from Chemical fertilizer and 40% from Cow dung (T_4) 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 fruits grown on plants received no supplemented nutrients (T_6) irrespective of years.

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, titrateable 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.

T_1 = 100% RD as per STB, T_2 = 125% RD as per STB, T_3 = 80% RD as per STB from Chemical fertilizer + 20% from Cow dung, T_4 = 60% RD as per STB from Chemical fertilizer + 40% from Cow dung, T_5 = Existing Practice CD, T_6 = Control

3.4. 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 techniques are illustrated in Tables 6 and 7. Through the study, highest net return per plant of Tk. 698.8, Tk. 760.0 and Tk. 816.0 was obtained by the year 2012, 2013 and 2014 respectively from 60% RD as per STB from Chemical fertilizer + 40% from Cow dung (T_4) while a lowest net benefit of Tk. 417.0, Tk. 484.2 and Tk. 539.4 were obtained from plants received no fertilizer (T_6) in the year 2012, 2013 and 2014 respectively.

However, the dominance analysis showed 1 of the 6 treatments unacceptable for investment for the growers because of other options having higher net benefits at comparatively low variable cost (cost dominated) irrespective of years, thus departing that treatment from the marginal rate of return (MRR) analysis.

Table 6. 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% RD as per STB, T₂ = 125% RD as per STB, T₃= 80% RD as per STB from Chemical fertilizer + 20% from Cow dung. T₄= 60% RD as per STB from Chemical fertilizer + 40% from Cow dung, T₅= Existing Practice CD, T₆= Control

The MRR analysis showed that the highest marginal rate of return (MRR) of 5090%, 5060% and 6484% was obtained from the treatment T₄ (60% RD as per STB from Chemical fertilizer + 40% from Cow dung) followed by T₂ (125% RD as per STB from Chemical fertilizer). MRR values for changing from the no-fertilizer control to chemical fertilizer were 4640%, 4560% and 4000% while changing from chemical fertilizer to integration of organic and inorganic nutrients (T₃) were 278%, 225% and 274% in 2012, 2013 and 2014 respectively. Hence, application of 60% RD of nutrients as per STB from Chemical fertilizer + 40% from Cow dung for mandarin orange plant would be economically acceptable for the growers.

Table 7. 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% RD as per STB, T₂ = 125% RD as per STB, T₃= 80% RD as per STB from Chemical fertilizer + 20% from Cow dung. T₄= 60% RD as per STB from Chemical fertilizer + 40% from Cow dung, T₅= Existing Practice CD, T₆= Control

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 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 researchers [19] 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. Scientists observed that citrus trees may not grow suitably without proper Nitrogen (N), Phosphorus (P) and potassium (K) supply [20]. Moreover, organic matter permits better aeration, enhances the absorption and release of nutrients, and makes the soil less susceptible to leaching and erosion [21, 22]. 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 results poor yield.

Maximum height and volume of plants were due to application of 60% RD of nutrients as per STB from Chemical fertilizer + 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. The increase in plant height and girth might be due to improvement of physical properties of soil, evidenced enhanced growth described [23]. Some 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 [24].

Plant growth characters significantly affect the yield contributing characters and yield. As the growth parameters boosted up, there was an option for accumulating more food in the amplified area excellently pursued for gathering of dry matter grants larger opportunity for higher production. In the present experiment plants received nutrients from both organic and

inorganic sources exhibited more number of fruits in each plant along with higher yield per plant and yield efficiency 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 was supported by some researchers in banana [25]. Chemical fertilizers along with organic soil amendments enriched the soil fertility escorting to elevated yield [6]. Application of chemical fertilizer for NPK plant nutrients gave significant fruit yield of mandarin cv. Kinnow [26]. Average 17-157% fruit yield over control was obtained by applying Mg in together with NPK. 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 [1]. Significantly positive correlation was found from the relationship between plant volume (m^3) and yield efficiency (kg/plant/ m^3).

For achieving high efficiency and lofty fruit quality orchard management should be done by proper nutrient organization. In the present experiment varying nutrient management affects the fruit quality. 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 that are mainly supplied by organic manure facilitates carbon buildup and sustained release of available nutrients to the plants [27, 28, 29]. Application of different nutrients through inorganic fertilizers, manures and biofertilizers increased the soil nitrogen, phosphorus and potassium contents [30, 31] improve fruit quality [32, 33, 34, 35] which is rather sensitive to K availability [36]. 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. Greater physical fruit quality was also for the reality that, nutrient availability of soil was enhanced by organic manures and fertilizers triggers the potential of plants to uptake considerable amount of solute from rhizosphere. The above findings are in accordance with other scientists [37, 38] in sapota. 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 [39] in mango and [38] 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. Similar findings have been reported by other researchers [23, 40, 41, 42] ascribed to uptake of more nitrogen and potassium in plant system increased total sugars in fruit due to accumulation of more photosynthates [43]. Uptake of magnesium, calcium, and ammonium N is prohibited by high K availability in the soil deteriorate juice properties regards titratable acidity [36]. Maximum total soluble solid (%) from fruits grown on those trees received $N_{300}P_{125}K_{225}Mg_{30}$ g/plant/year [1]. Fertilizing positively influence in quality of citrus fruit [44, 45, 46] concluded that 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 fruit [47] 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 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, are in accordance with [1]. Erosion and organic matter reduction of soil may increases bulk density affects soil quality

lead to lower yields and/or higher costs of production [47] thus for costs reduction along with maintaining soil physical, chemical and biological properties producers should use of organic nutrient [48]. 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% RD of nutrients as per STB from Chemical fertilizer + 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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