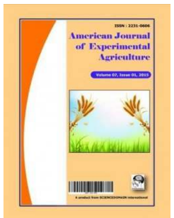

American Journal of Experimental Agriculture
10(6): 1-14, 2016, Article no.AJEA.22580
ISSN: 2231-0606

SCIENCEDOMAIN *international*
www.sciencedomain.org

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

M. H. M. B. Bhuyan[1], J. C. Sarker[1], S. M. L. Rahman[1], Masayuki Fujita[2] and Mirza Hasanuzzaman[3]*

[1]Citrus Research Station, Bangladesh Agricultural Research Institute, Jaintiapur, Sylhet, Bangladesh.
[2]Laboratory of Plant Stress Responses, Faculty of Agriculture, Kagawa University, Japan.
[3]Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, 1207, Bangladesh.

Authors' contributions

This work was carried out in collaboration with all authors. Author MHMBB designed the study, wrote the protocol, executed the experiment, performed the statistical analysis and wrote the first draft. Authors JCS and SMLR reviewed the design and all drafts of the manuscript, identified the plants and managed soil and other analysis of the study. Authors MF and MH gave suggestions for executing the study properly, reviewed all the activities and reviewed each drafts of the manuscripts. All the authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJEA/2016/22580
Editor(s):
(1) Lanzhuang Chen, Laboratory of Plant Biotechnology, Faculty of Environment and Horticulture, Minami Kyushu University, Miyazaki, Japan.
Reviewers:
(1) Ragaa A. Hamouda, University of Sadat City, Egypt.
(2) A. Tikader, Ministry of Textiles, Govt. of India, India.
(3) Anonymous, Norwegian Institute for Agricultural and Environmental Research, Norway.
Complete Peer review History: http://sciencedomain.org/review-history/12559

Original Research Article

Received 12th October 2015
Accepted 24th November 2015
Published 4th December 2015

ABSTRACT

The study was aimed at boosting up the yield and profitability of mandarin orange cultivation through integrated nutrient management. 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. Growth, yield and qualitative parameters were found to be influenced by different nutrient management options. Plants received 60% of their required nutrients as per soil test basis from chemical fertilizer and 40% from

*Corresponding author: E-mail: mhzsauag@yahoo.com;

Cow dung (T_4) were found best with yield and qualitative parameters along with highest marginal rate of return. Hence, this may be a wise and economic choice for farmers, producing mandarin orange var. BARI Manderin-1 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 all available plant nutrient sources, organic and inorganic, to provide optimum and sustainable productivity as well as conserving soil health. [1]. 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/l00 ml 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 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 [5-8]. Huchche et al. [9] found increased yield of Mandarin in the course of applying organic amendments to soil with different chemical fertilizers. 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. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at Citrus Research Station, Bangladesh Agricultural Research Institute (BARI), Jaintiapur, Sylhet (25.13562ºN latitude, 92.13217ºE longitude, 36m of elevation from mean sea level), Bangladesh in three consecutive years viz. 2012, 2013 and 2014. 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 36ºC and 6ºC 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].

2.2 Designing Experimental Treatments

The physico-chemical properties of the soil were analyzed before every experimental year for knowing the recommended dose of nutrients for mandarin on soil test basis (STB). 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).

2.3 Cultural Management

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

Dolomite (agricultural lime) 4 kg/decimal was applied only in the first year of experiment in every treatment 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. 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. Fertilizers were applied radialy 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.

2.4 Growth, Yield Attributes and Yield Measurement

Data were recorded on growth parameters namely, percent growth in plant height, tree volume (m^3), fruits per plant, yield per plant (kg) and yield efficiency (kg/m^3). Following Castle et al. through minor amendment, tree volume were calculated via the formula V (m^3) = π /6× H ×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].

2.5 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].

2.6 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 (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 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 MRR of 50% is acceptable for the farmers to shift from one nutrient management option to other without learning fresh skills. Thus, any treatment that gave MRR exceeding 50% is considered admirable for farmers' investment [17-19].

2.7 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 was performed for mean separations and interpretation of results [20].

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 (Figs. 1 and 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 (T_4) grows vigorously and reached up to 193.4 cm in height on an average with 2.71 m^3 of tree volume, which was also emulated in the second year of the study (212.8 cm height and 3.58 m^3 of tree volume respectively). But in the third year of study more vigorosity (235.0 cm height and 4.36 m^3 of tree volume) was found from the plants received 80% of required nutrients as per STB from chemical fertilizer and 40% from Cow dung (T_3). While comparatively weak plants was found from the plants grows on soil's native nutrients (T_6). In all three years of experiment, T_1 and T_2 showed intermediate vigor.

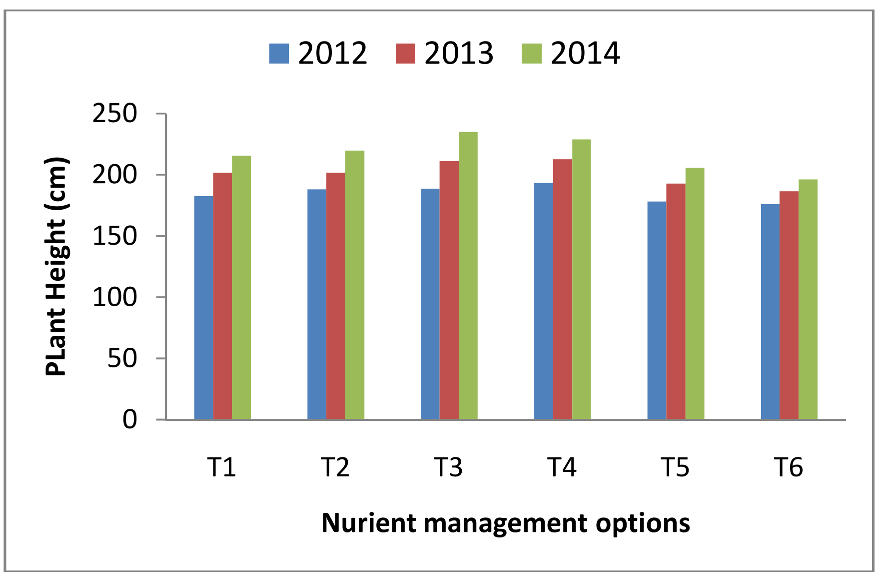

Fig. 1. Effect of integrated nutrient supply on height of mandarin oranges trees

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)

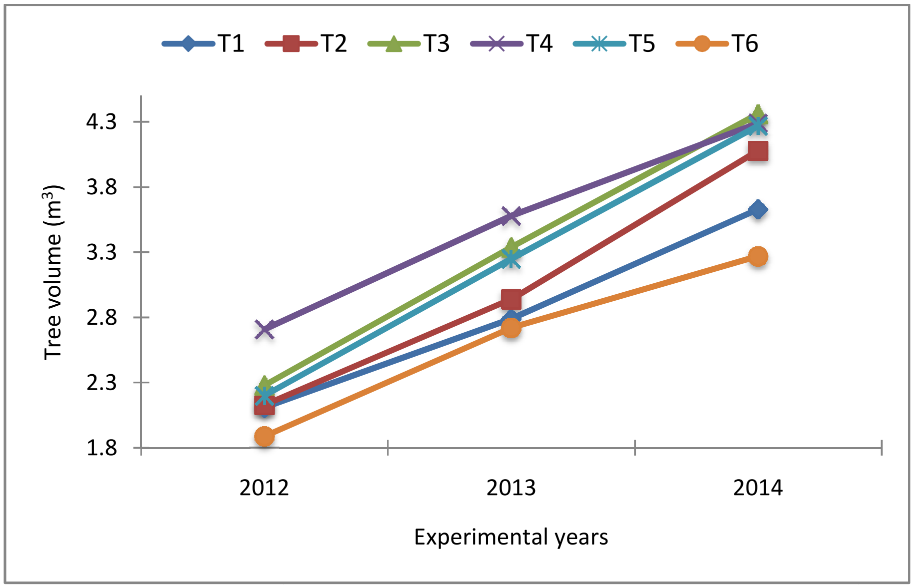

Fig. 2. Effect of integrated nutrient supply on tree volume of mandarin oranges plants

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)

3.2 Yield

Effects of integrated nutrient supply showed similar variations on yield characters also. In all the experimental years less productivity was obtained from the control treatment where the plants grown under native nutrient status of soil (T_6). These plants retained less number of fruit with comparatively small fruit (data not presented) of lower individual fruit weight resulting little yield per plant and lower yield efficiency (Fig. 3). Throughout the experiment maximum number of fruit, yield and yield efficiency was carried by the plants received 60% recommended nutrients as per STB from Chemical fertilizer and 40% from Cow dung (T_4) demonstrating the influence of integrated management together with organic and inorganic nutrients at par with the plants received 80% recommended nutrients as per STB from Chemical fertilizer and 20% from Cow dung (T_3). However, use of chemical fertilizers solely (T_1) or even in higher dose than recommendation (T_2) didn't give a significant variation respect to fruits per plant, yield and yield efficiency.

Superior performance regards to yield efficiency (Kg/m^3) was found from T_4 (60% recommended nutrients as per STB from Chemical fertilizer and 40% from Cow dung) although decreased through out the experimental period (Fig. 4). Whereas least yield efficiency was found from T_6 (Native nutrient) in all the experimental years (2012, 2013 and 2014 respectively).

3.3 Fruit Quality

The plants treated with 60% recommended nutrients as per STB from Chemical fertilizer and 40% from Cow dung (T_4) produced the heaviest fruit throughout the experimental period. Although the individual fruit weight gradually decreased, but produced larger fruits than that of other treatments. Whereas the plants received no nutrients yielded the lightest fruit (Fig. 5). There were no significant difference among the treatments regarding segments per fruit in the first year of study but in the later years slight variations were noticed. Maximum number of segments per fruit was counted from T_3 and T_5 in the year 2013 and T_6 in the year 2014 (Fig. 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 T_4 (60% recommended nutrients as per STB from Chemical fertilizer and 40% from Cow dung) while T_3 (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 (Fig. 7).

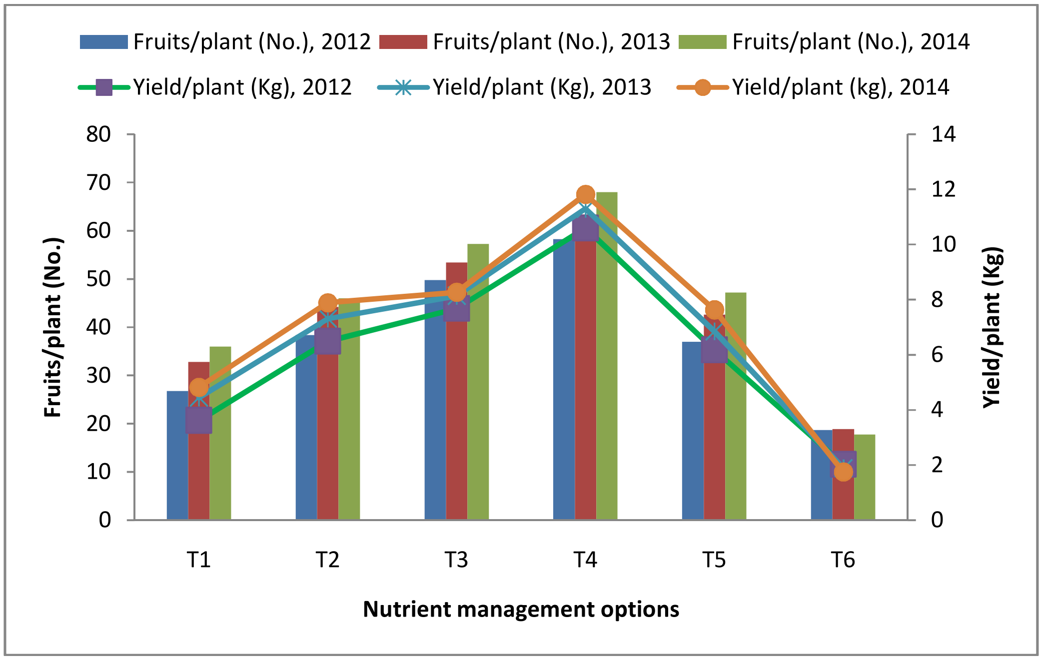

Fig. 3. Number of fruits per plant and per plant yield (kg) of Mandarin as influenced by integrated nutrient supply

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)

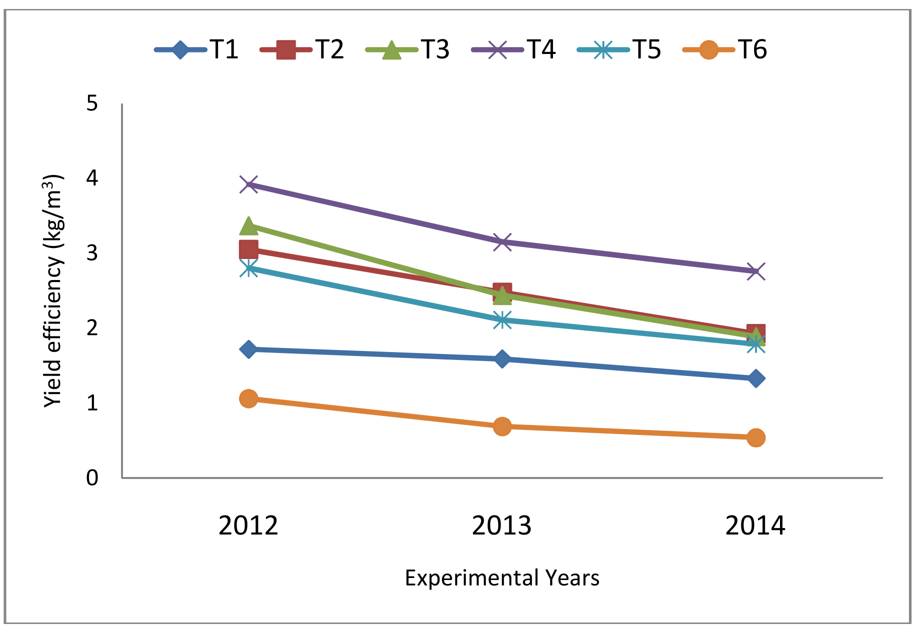

Fig. 4. Yield efficiency (kg/m^3) of Mandarin as influenced by interated nutrient supply

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)

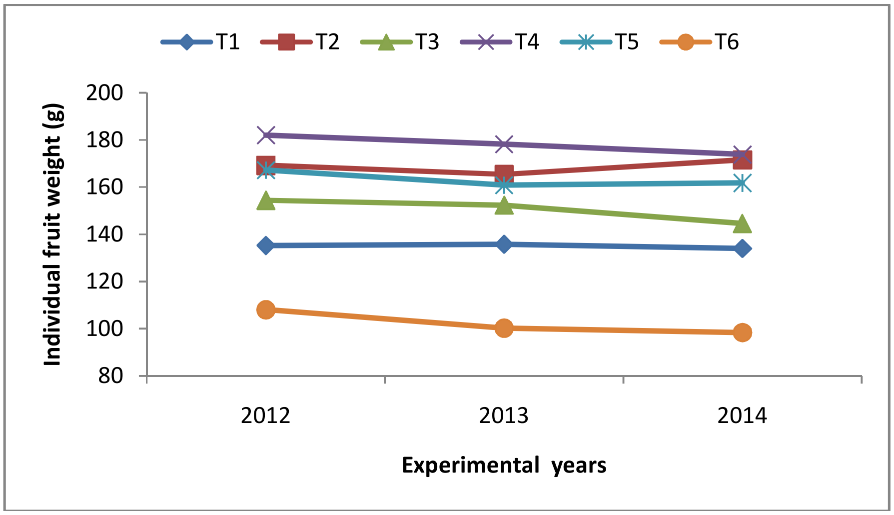

Fig. 5. Influences of integrated nutrient management on individual fruit weight of mandarin orange

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)

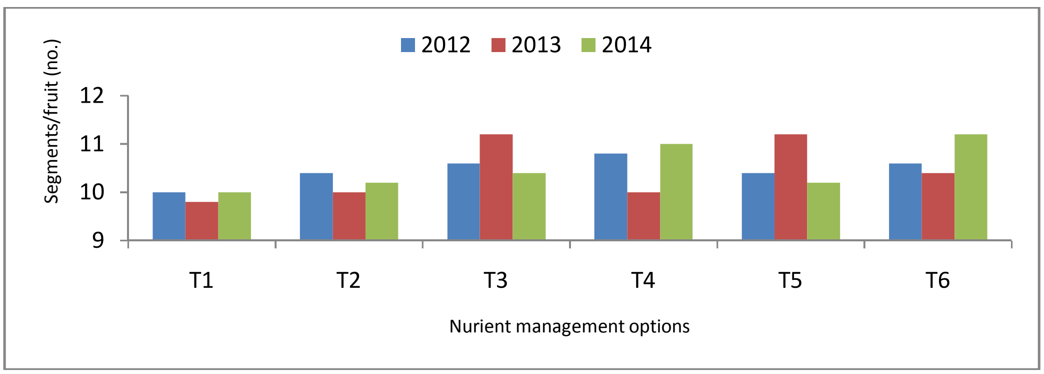

Fig. 6. Influences of integrated nutrient management on segments/fruit of mandarin orange

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)

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 plants receiving only chemical nutrients (T_1 & T_2) produced fruits with thick (data not presented) and heavy rind, whereas fruits from control plots had very much thin rind with minimum weight. But organic nutrients (T_5) or integration of organic and inorganic nutrients (T_3 & T_4) gave the most suitable rind with medium weight which ensured the fruit quality (Fig. 8).

Juice percentage of fruits increased compared to the control in all the test years, from trees received nutrients from both organic and inorganic sources (Fig. 9). In 2012 plants received 60% recommended nutrients as per STB from Chemical fertilizer and 40% from Cow dung (T_4) 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 (T_3) produced most juicy fruits revealed the effects of integrated nutrient on the juice content.

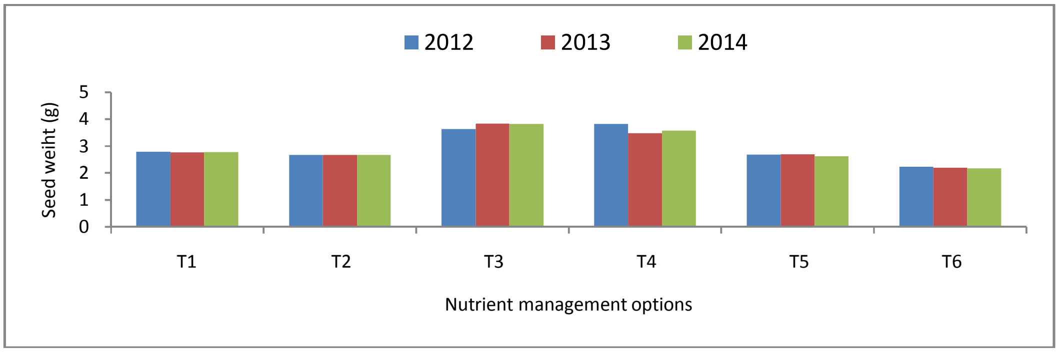

Fig. 7. Influences of integrated nutrient management on seed weight of mandarin orange
T_1= 100% Recommended Dose(RD) of nutrients as per STB (Soil test basis) from Chemical fertilizer, T_2 = 125% RD of nutrients as per STB from Chemical fertilizer, T_3 = 80% RD of nutrients from Chemical fertilizer + 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)

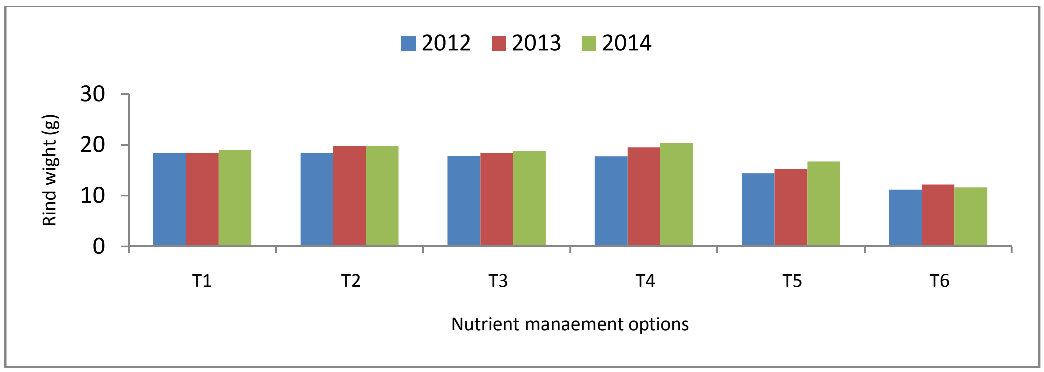

Fig. 8. Influences of integrated nutrient management on rind weight of mandarin orange
T_1= 100% Recommended Dose(RD) of nutrients as per STB (Soil test basis) from Chemical fertilizer, T_2 = 125% RD of nutrients as per STB from Chemical fertilizer, T_3 = 80% RD of nutrients from Chemical fertilizer + 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)

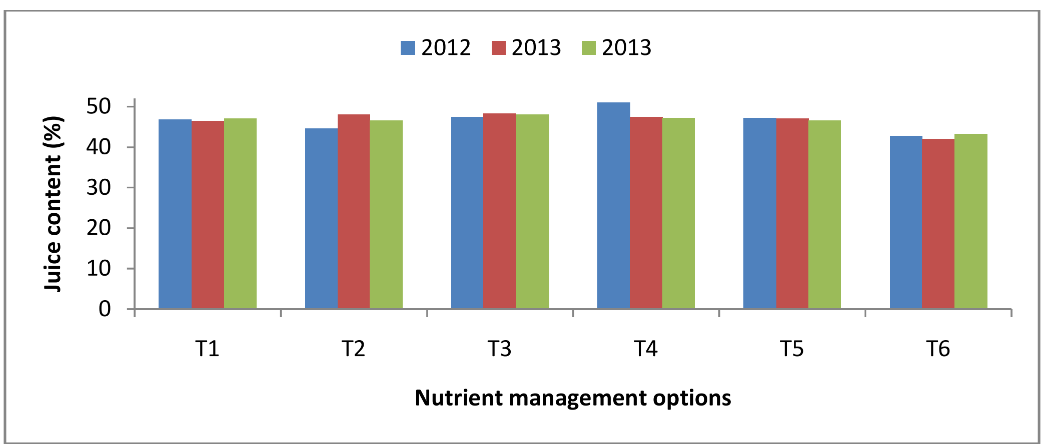

Fig. 9. Juice content (%) as influenced by different integrated nutrient management options
T_1= 100% Recommended Dose(RD) of nutrients as per STB (Soil test basis) from Chemical fertilizer, T_2 = 125% RD of nutrients as per STB from Chemical fertilizer, T_3 = 80% RD of nutrients from Chemical fertilizer + 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)

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 (T_3) 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 (Fig. 10). Titratable 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 (T_3) 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 (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 the fruits of plants received no supplemented nutrients (T_6) irrespective of years (Fig. 11).

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 process is illustrated in Tables 1 and 2. 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 T_4 (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 (T_6) in the year 2012, 2013 and 2014 respectively.

However, the dominance analysis showed, one treatment is unacceptable for investment for the growers because of the others 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.

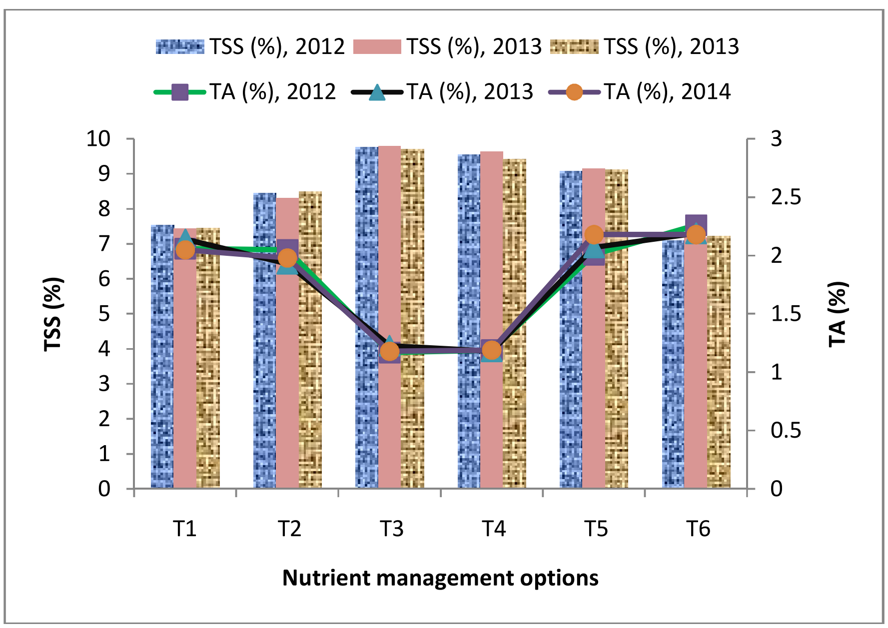

Fig. 10. TSS (%) and TA (%) as influenced by different integrated nutrient management options

TSS, total soluble solids; TA, titratable acidity; 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)

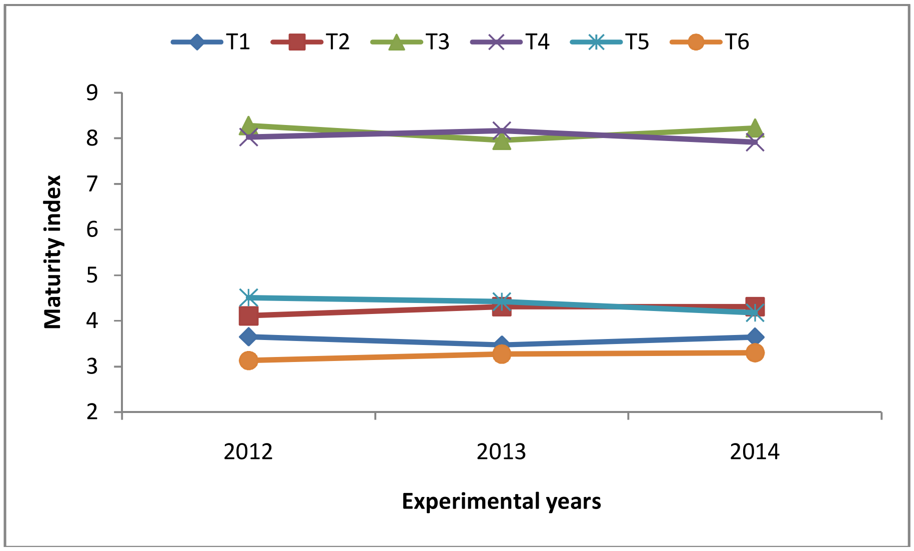

Fig. 11. Maturity index as influenced by different integrated nutrient management options

MI, Maturity Index (TSS/TA); 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)

The MRR analysis showed that the highest marginal rate of return (MRR) was obtained from the treatment T_4 (60% recommended nutrients as per STB from Chemical fertilizer and 40% from Cow dung) at par with T_2 (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 2). 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.

4. DISCUSSION

A significant increase in terms of growth, yield and profitability of mandarin production due to integration of organic and inorganic nutrients perhaps assisted sustaining productiveness corroborates with other researchers [21]. Some scientists observed that citrus trees may not grow suitably without inorganic nutrients [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].

Maximum height and volume of plants were found with application of 60% recommended nutrients as per STB from Chemical fertilizer and 40% from Cow dung (T_4) revealed that integration of inorganic and organic nutrients to soil improves 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.

As the growth parameters boosted up, there was an opportunity for accumulating more food and dry matter that helps in higher production. In the present experiment plants that received nutrients from both organic and inorganic sources exhibited more number of fruits per plant, aided higher yield and yield efficiency. This might be due to faster vegetative growth, progress in photosynthesis rate and improvement of the photosynthates translocation. This result is in conformity with other researchers in banana [27]. In contrary Monga et al. found chemical fertilizer best for sustainable fruit yield of kinnow mandarin [28], but our result doesn't corroborates with them.

Table 1. 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

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), Tk-Taka (Currency of Bangladesh), CU-Cost un-dominated, CD-Cost dominated

Table 2. 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	-	-	-	-	-	-	-	-	-

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), Tk-Taka (Currency of Bangladesh)

Integrated nutrient management affects the fruit quality respect to individual fruit weight, number of segments per fruit, seed weight and rind weight per fruit that also confirmed by others [29-31]. Application of different nutrients through inorganic fertilizers, manures and biofertilizers increased the soil nitrogen, phosphorus and potassium contents [32,33] improve fruit quality [34-37] 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. Superior fruit quality was also for the fact that, combimed application of organic and inorganic manure enhance soil nutrient availability triggers the plants to uptake considerable amount of solute from rhizosphere also supported by other scientists [39,40]. 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 Madhavi et al. [41] Alva and Paramasivam [42].

Significant difference also found in terms of juice percent, juice total soluble solids, titratable acidity and maturity index also. Similar findings have been reported by other researchers [25,42, -45]. Alva et al. found 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 (%) which supports the present findings. Fertilizing also influence in quality of citrus fruit [46-48] 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.

The greatest challenge for farmers is to gain a product at a price that allows a profit which will also fulfill the consumers' requirement. Use of different levels of integrated nutrient management affects 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Miah MMU, Jahiruddin M, Islam MF, Razia MS, editors. Fertilizer recommendation guide-2005. The Bangladesh Agricultural Research Council; 2005.
2. Nasreen S, Ahmed R, Ullah MA, Hoque MA. Effect of N, P, K, and Mg application on yield and fruit quality of mandarin (*Citrus reticulata*). Bangladesh J Agril Res. 2013;38(3):425-433.
3. Islam S, Miah S, editors. Banglapedia: National encyclopedia of Bangladesh. Asiatic Society of Bangladesh; 2003.
4. Hasan GMJ, Alam R, Islam QN, Hossain MS. Frequency structure of major rainfall events in the north-eastern part of Bangladesh. J Engi Sci Technol. 2012; 7(6):690-700.
5. Ghose SN. Nutritional requirement of sweet orange *(Citrus sinensis)* cv. Mosambi. Haryana J Hort Sci. 1990;19:39-44.
6. Kumar R, Ahalawat VP, Daulata BS. Growth, yield and quality attributes of Kinnow (*C. reticulata)* as affected by nitrogen and phosphorus application. Haryana J Hort Sci. 1993;22:8-13.
7. Ram L, Kohli RR, Srivastava AK, Huchche AD, Das HC. Nutritional requirement of Nagpur Mandarin (*C. reticulata)* grown on vertisol in central region. Indian J Hort. 1997;54:91-97.
8. Shukla AK, Goswami AM, Saxena SK, Sharma RR, Pratap B. Effect of nitrogen

and phosphorus on growth and yield of Kinnow under high density planting. Ann Agric Res. 2000;2:540-543.
9. Huchche AD, Landaniya MS, Ram L, Kohli RR, Srivastava AK. Effect of nitrogenous fertilizers and farm yard manure on yield, quality and shelf life of Nagpur Mandarin. Indian J Hort. 1998;55(2):108-112.
10. Calvert DV. Response of temple oranges to varying rates of nitrogen, potassium and magnesium. Proc Fla Hort Soc. 1970;3:10-15.
11. Ram RA, Rajput MS. Role of biofertilizers andmanures in production of guava (*Psidium guavajava* L.) cv. Allahabad Safeda. Haryana J Hort Sci. 2000;29:193-194.
12. Castle SW. Growth yield and cold hardiness of seven Bears lemon trees on twenty seven rootstocks. Proc State Hort Soc. 1983;96:23-25.
13. Cantuarias-Avilés T, Mourão Filho FAA, Stuchi ES, Silva SR, Espinoza-Nunez E. Tree performance and fruit yield and quality of 'Okitsu' Satsuma mandarin grafted on 12 rootstocks. Sci Hort. 2010;123:318–322.
14. Hardy S, Sanderson G. Prime fact 980, Citrus maturity testing. Department of industry and investment (industry & investment NSW), State of New South Wales, Australia. 2010;1-6. Available:http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0020/320294/Citrus-maturity-testing.pdf (Accessed 12 April 2015)
15. Sherwood SF. Use of the refractometer in the analysis of Individual sugar beets. J Agric Res. 1928;36(1):41-52.
16. Cavalcante IHL, Martins ABG, Stuchi ES, Campos MCC. Fruit maturation as a parameter for selection of sweet orange cultivars in Brazil. J Food Agric Env. 2009;7(3&4):316–319.
17. Asumadu H, Sallah PYK, Boa-Amponsem PB, Allou J, Manu-Aduening, Osei-Bonsu. On-farm evaluation and promotion of quality protein maize hybrids in Ghana. African Crop Sci Proc. 2004;4:358-364.
18. International Wheat and Maize Improvement Center (CIMMYT). An economic training manual: From agronomic data to farmer recommendations; 1988.
19. Dillon JL, Hardaker JB. Farm management research for small farmer development. FAO Systems Management Series 6; 1993.
20. Gomez KA, Gomez AA. Statistical procedures for agricultural research. 2nd ed. New York: John Wiley and Sons; 1984.
21. Baligar VC, Fageria NK, He ZL. Nutrient use efficiency in plants. Commun Soil Sci Plant Anal. 2001;32(7&8):921–950.
22. Obreza TA, Zekri M, Hanlon EW. Soil and leaf tissue testing. In: Obreza TA, Morgan KT, editors. Nutrition of Florida Citrus Trees. 2nd ed. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida; 2008.
23. Sekhon GS, Meelu OP. Organic matter management in relation to crop production in stressed rainfed systems. In: Virmani SM, Katyal JC, Eswaran H, Abrol IP, editors. Stressed ecosystems and sustainable agriculture, New Delhi: Oxford University Press and IBH Publishing; 1994.
24. Reijntjes C, Haverkort B, Waters-Bayer A. Farming for the future. An Introduction to Low External Input and Sustainable Agriculture. ILEIA, Leusden; 1992.
25. Kumar D, Pandey V, Anjaneyulu K. Effect of planting density and nutrient management on growth, yield and quality of micro propagated banana Rasthali (AAB-Pathkapoora). Indian J Hort. 2008; 65:272-276.
26. Hassan MA, Singh B, Das BC, Suresh CP. Banana production as influenced by nitrogen and potassium nutrition. Orissa J Hort. 2001;29:63-73.
27. Chezhigen N, Balasubramani P, Harris CV, Anathan M. Effect of inorganic and biofertilizers on growth and yield of hill banana var. Virupakashi. South Indian Hort. 1999;47:1-6.
28. Monga PK, Vij VK, Sharma JN. Effect of N, P and K on the yield and fruit quality of Kinnow mandarin. Indian J Hort. 2004; 61(4):302-304.
29. Goel S, Chander K, Mundra MC, Kapoor KK. Influence of inorganic fertilizer and organic amendments on soil organic matter and soil microbial properties under tropical conditions. Biol Fertil Soils. 1999;29:196-200.
30. Singh GR, Pandey KS, Chaure NK, Parihar SS, Choudhury K. Soil fertility productivity and profitability of rice under different organic manures. Oryza. 2000;37:208-212.

31. Datta M, Singh NP. Nutrient management in rice-based cropping system as influenced by applying cattle manure alone or in combination with fertilizers in upland acid soil of Tripura. J Indian Soc Soil Sci. 2010;58:94-98.
32. Dutta P, Kundu S, Biswas S. Integrated nutrient management in litchi cv. Bombai in new alluvial zone of West Bengal. Indian J Hort. 2010;67:181-184.
33. Prasad J, Karmakar S, Kumar R, Mishra B. Influence of integrated nutrient management on yield and soil properties in maize-wheat cropping system in an Alfisol of Jharkhand. J Indian Soc Soil Sci. 2010;58:200-204.
34. Ram RA, Prasad J. Effect of nitrogen, phosphorus and potassium on fruit quality of banana cv. Campirganj Local (*Musa*-ABB). South Indian Hort. 1988;36:290-292.
35. Natesh BB, Arbindakshan M, Valsalakumar RK. Effect of split application of fertilizers in banana *Musa* AAB 'Nendran'. South Indian Hort. 1993;41:67-73.
36. Pandey V, Kumar D, Naik G. Performance of micro-propagated banana Robusta at varying combinations of spacing and nitrogen nutrition in rainfed lateritic soils of coastal Orissa. Prog. Hort.2005;37:260-268.
37. Srinivas K, Reddy BMC, Chandra Kumar SS, Gowda T, Raghupati HB. Padma P. Growth, yield and nutrient uptake of Robusta banana in relation to N and K fertigation. Indian J Hort. 2001;58:287-293.
38. Alva AK, Mattos Jr.D, Paramasivam S, Patil B, Dou H, Sajwan KS. Potassium management for optimizing citrus production and quality. Int J Fruit Sci. 2006;6(1):3-43.
39. Gawande SS, Jitonde DJ, Turkhede AB, Darange SO. Effect of organic and inorganic fertilizers on yield and quality of sapota. J Soils Crops. 1998;8(1):58-60.
40. Patel DR, Naik AG. Effect of pre-harvest treatment of organic manures and inorganic fertilizers on post harvest shelf life of sapota cv. Kalipatti. Indian J Hort. 2010;67(3):381-386.
41. Madhavi A, Maheswara VP, Girwani A. Integrated nutrient management in mango. Orissa J Hort. 2008;36(1):64-68.
42. Alva AK, Paramasivam S. Nitrogen management for high yield and quality of citrus in sandy soils. Soil Sci Soc Am J. 1998;62:1335-1342.
43. Koo RCJ, Reese RL. Influence of fertility and irrigation treatments on fruit quality and 'Temple' orange. Proc Flo State Hort Soc. 1976;89:49-51.
44. Reese RL, Koo RCJ. N and K fertilization effects on leaf analysis, tree size and yield of three major Florida orange cultivars. J Am Soc Hort Sci. 1975;100:195-198.
45. Kato T. Nitrogen metabolism and utilization in citrus. Hort Rev. 1986;8:181-216.
46. Pozzan M, Triboni HR. Colheita e qualidade do fruto. In: Mattos Júnior D, Negri JD, Pio RM, Pompeu Jr. J, editors. Citros. Campinas: Instituto Agronômico e Fundag; 2005. (Portuguese).
47. Chapman HD. The mineral nutrition of citrus. In: Reuther W, Batchelor LD, Webber HJ, editors. The citrus industry. University of California, Div Agric Sci, Berkeley, CA, USA. 1968;2.
48. Embleton TWH, Reitz HJ, Jones WW. Citrus fertilization. In: Reuther W. editor. The Citrus Industry. University of California, Div Agric Sci, Berkeley, CA, USA. 1973;3.
49. Ramos DP, Dalastra IM, Evangelista RM, Leonel S, Mischan MM. Influência da posição do fruto na qualidade de laranja 'folha murcha' e tangerina 'poncã'. In: Congresso Brasileiro De Fruticultura, 21., 2010, Natal. Anais... Natal, 1CD; 2010. (Portugese).
50. Kumar PS, Choudhary VK, Kanwat M, Sangeetha A. Influence of different sources of nutrients on growth, yield and quality of Khasi mandarin grown under mid hills of Arunachal Pradesh (India). J Appl Hort. 2013;15(3):220-223.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/12559