Reduction of Chemical Fertilizer Usage in Mandarin Orchard and Effects on Yield and Quality of Mandarin Fruits: On Farm Trial at Fang District, Chiang Mai Province

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ABSTRACT

A field experiment was conducted in mandarin orchard of a farmer in Fang district, Chiang Mai province in order to evaluate the effects of reduction of the chemical fertilizer usage on yield and quality of mandarin fruits. The soil in the orchard had pH of 5.0 and contained high level of soil organic matter (2.5-3.0%), very high level of available P (>100 mg P/kg) and high level of exchangeable K (100-300 mgK/kg). The experimental design was randomized complete block with 5 replications and 4 treatments. In the first treatment, soil application of N, P and K fertilizers including foliar spraying of fertilizer according to farmer practice (NPK+FL) was used. In the second, third and fourth treatments, soil application of P and K fertilizers were omitted. In the second treatment, the same rates of N and foliar fertilizer spraying were the same as those in Tr.1 (-PK+N+FL). In the third treatment, the same rate of N fertilizer as used in Tr.2 was applied but foliar fertilizer was used according to the data of leaf analysis (-PK+N+fl). In the fourth treatment, the same rate of foliar fertilizer spraying as used in Tr.3 was applied while N fertilizer was applied according to N removal by fruit yield plus additional N to compensate N lost by leaching about 40% of N removal by fruit yield (-PK+n+fl). The collected data were, in season fruit yields harvested in December 2008 and January 2009, fruit sizes and the content of soluble solid of the fruits. It was found that in Tr.1, the total fruit yield was 80 kg/tree of which 56% were no.5 size and those with no.6 and no.4 sizes were 19 and 16% respectively. The content of soluble solid was 10.8 °brix for the fruits in the first harvest while those in the second harvest were 11.5 °brix. There were no significant differences of fruit yields and fruit qualities among the four tested fertilizer application rates. In Tr.2, the cost of input on fertilizer application could be reduced 57% compared to that of Tr.1 while in Tr.3 and Tr.4 the costs of inputs were reduced 88 and 97%.

Key words: Mandarin orchard, Reduction of chemical fertilizer, Soil and foliar application, Fruit yield, Fruit quality

INTRODUCTION

Chiang Mai province is the largest mandarin (*Citrus reticulata* Blanco) producing area of Thailand. The total cultivated area in 2009 is 67,221 rais (10,755.36 ha) which 94% are in Fang, Mae Ai and Chaiprakarn districts. Ninety six percent of the farmers grow 'Sai Nam Pueng' mandarin variety. At present, mandarin cultivated area has been reduced compared with that in 2007 due to the low price of mandarin fruits particularly at the time of the high peak of fruit production, reduced market share due to imported citrus fruits, less demand from overseas markets, high cost of inputs and environmental problems from over doses of agrochemical application (Chiang Mai Agricultural Office, 2009). From the study of Virunrat et al. (2011) the status of soil fertility and plant nutrient contents of the leaves of mandarin trees in the orchards of fifty farmers at Mae Soon

sub-district, Fang district, Chiang Mai province including fertilizer management by the farmers were reported. They found that the soils from all studied mandarin orchards of the farmers from the different topographical areas were high in available P and exchangeable K. The commonly used chemical fertilizers by the farmers were 15-15-15 and 13-13-21 at the rate within the range of 0.5-1.0 kg/tree per month. All farmers applied foliar fertilizer all year round every 10 days. Cu containing fungicides were also used for disease controlling by leaf spraying. Leaf analysis data indicated that mandarin trees in the farmers' orchards contained optimum levels of plant nutrients. The higher levels of available P and exchangeable K in the mandarin orchard soils than the optimum values may be due to long term application of mixed fertilizers containing N, P and K at the high doses. Such farmer practices may not have any effect on improvement of mandarin fruit yield and fruit qualities. Furthermore, long term application of improper rates of chemical fertilizer could create plant nutrient imbalance which subsequently affect availabilities of plant nutrients in the soil and also nutrient assimilation of the plant (He et al., 2003). The proper rates of plant nutrients for mandarin production can be estimated from the status of plant nutrients in the soil and in the leaves including the nutrient removal by crop yield. With proper fertilizer management, the input cost for fertilizer can be reduced and mandarin trees can be productive in the long run.

This study was conducted in order to find out the possibility to reduce fertilizer application rates for mandarin production in the farmer orchard. The data being obtained could be used for recommendation of the proper fertilizer management to mandarin farmers.

MATERIALS AND METHODS

One farmer orchard located in Pong Num Ron sub district, Fang district was selected as the study site. The area is slightly sloping area with good drainage. The orchard has eastern slope aspect, thus the mandarin trees in this orchard can get sunshine from the morning until 12.00 o'clock which is suitable for mandarin cultivation.

'Sai Num Pueng' mandarin trees in this orchard were about 4-5 years old. They were grown on troyer root stocks. There were 54 trees per rai (338 trees /ha). Before the trial the soil had pH of 5.0, and contained high level of soil organic matter (2.5-3.0%), very high level of available P (>100 mg P/kg) and a high level of exchangeable K (100-300 mg K/kg).

The on farm fertilizer trial was conducted during June 2008 - January 2009. The experiment design was randomized complete block with 5 replications and 4 treatments. In the first treatment, soil application of N, P and K fertilizers (Table 1) and spraying of foliar fertilizers and hormone (Table 2) according to farmer's practices (NPK+ FL) were used. In the other three treatments, soil application of P and K fertilizers were omitted because the soil in the experimental plots were rich in available P and exchangeable K. Urea was applied into the soil for the second and third treatments at the same rate of N as that in treatment 1. The same foliar spraying of fertilizer and hormone as used in treatment 1 was applied in the second treatment (-PK+N+FL) while foliar spraying of trace element was used according to nutritional status of the leaves by leaf analysis (-PK+N+fl) in the third treatment. In the fourth treatment, the rate of N application was estimated by N removal by the expected mandarin fruit yield (70 kg/tree) plus additional N to compensate N lost by leaching about 40% of N removal by fruit yield. The same foliar spraying of trace elements as used in Treatment 3 was applied in the fourth treatment (-PK+n+fl). In the first and second treatments, foliar spraying of fertilizers and hormone was done every 7 days throughout the experimental period. According to leaf analysis data before the application of foliar spraying, the mandarin trees from treatment 4 were deficient in Zn. Thus, 'Fol-Max' foliar fertilizer containing Zn (70%Zn) was used in treatment 3and 4. Spraying of Fol-Max four times from the beginning of the trial to 15 October. After that no foliar spraying of Zn was used because the leaf analysis data indicated that the tree in treatment 3 and 4 had sufficient level of Zn. The rate of N, P_2O_5 and K_2O applied to soil in each treatment was shown in Table 3. For each treatment in each replication, there was one row of 11-13 mandarin trees. The first and the last trees in each row were considered as the borders. Throughout the experimental period, sprinkle irrigation and pest control by farmer

practices were used. The collected data were in season fruit yields harvested in December 2008 and January 2009, fruit sizes and the content of soluble solid or sweetness. The treatment effects were analyzed by F-test and the differences among the means were compared by least significant difference (LSD) at $P<0.05$.

Table 1. Soil application of fertilizers by farmer practice.

Date/Mo/Yr.	Fertilizer grade	Rate of application (kg/tree)
27 June 2008	13-13-21:15-15-15 (2:1)	1.0
9 August 2008	13-13-21:15-15-15:0-020 (1:1:1)	1.0
30 August 2008	dolomite	2.5
27 September 2008	13-13-21:0-0-22 (1:1)	1.0
20 October 2008	13-13-21:0-0-22 (1:1)	1.0
20 November 2008	22-0-0	1.0
13 December 2008	Hi-mag	1.0
20 December 2008	13-13-21:0-0-22 (2:1)	1.0

Table 2. Foliar spraying of fertilizers and algal extract by farmer practice.

Product	Rate of application /ha
CaB	1.50-3.0 L
Mg	0.75 L
Algal extract	1.88-3.00 L
Alzaiger[1]	0.38-0.75 L
Amino acid	3.00 L
Super K	4.50 kg
Fetilon[2]	0.19-0.38 kg

[1]Alzaiger contains Zn Mg and Mn
[2]Fetilon contains MgO, S, Fe, Mn, Cu, Zn, B and Mo

Table 3. Rate of N, P_2O_5 and K_2O applied in to the soil for each treatment.

Treatment	Rate of application (kg)					
	N		P_2O_5		K_20	
	per tree	per ha	per tree	per ha	per tree	per ha
NPK+FL	0.67	226.13	0.45	151.88	1.03	347.63
-PK+N+FL	0.67	226.13	0	0	0	0
-PK+N+fl	0.67	226.13	0	0	0	0
-PK+n+fl	0.08	28.12	0	0	0	0

RESULTS

There were no significant effects of fertilizer treatments on mandarin fruit yields at the first and second harvest including the total fruit yield (Table 4). For the first harvest only 28-37% of the total fruit yields were obtained while those in the second harvest were about 62-80%. By farmer practice (NPK+FL), mandarin trees gave total fruit yield about 75 kg/tree. When P and K fertilizers were omitted and the same rate of N and foliar spraying as used by farmer rate were applied

(-PK+N+FL), the total mandarin fruit yield of about 89 kg/tree was obtained. Reduction of the amount of fertilizer by foliar spraying and remaining the same rate of N application as used by farmer rate (-PK+N+fl), or even reduction of N application rate (-PK+n+fl), the trees still gave the total fruit yield about 83 kg/tree. The fertilizer application rates do not have significant effects on the content of soluble solid contents of the fruit at both harvests. At the first harvest, the content of the soluble solid of the fruits were in the range of 10.6-11 °brix while these at the second harvest were 11.5-12.0 °brix.

Table 4. Effect of fertilizer treatments on mandarin fruit yield at the first and second harvest, total fruit yield and the contents of soluble solid (°brix).

Data		Fertilizer treatment				CV(%)
		NPK+FL	-PK+N+FL	-PK+N+fl	-PK+n+fl	
1st yield (kg/tree)	ns	27.9	25.3	26.4	27.1	28.98
2nd yield (kg/tree)	ns	47.2	63.9	56.9	55.7	25.54
total yield (kg/tree)	ns	75.1	89.2	83.3	82.8	18.98
°brix 1st harvest	ns	10.9	10.6	10.6	11.0	6.97
°brix 2nd harvest	ns	11.5	11.8	11.5	12.0	6.60

ns = non significant

No significant effects of fertilizer treatments on the yield of mandarin fruits at different sizes were found (Table 5). Without P and K fertilizer applications, reduction of N rate and fertilizer application by foliar spraying (-PK+n+fl) almost the same yields of the fruits with different sizes as those by farmer rates were obtained. The yield of fruits with size 5, which was the most preferable size for the market, was highest (52-56%) followed by size 5 (18-19%) and size 4 (16-20%). The rest were size 2, 3 and 7.

Table 5. Effects of fertilizer treatments on the yields of mandarin fruits (kg/tree) with different sizes.

Fruit size	Fruit diameter (mm)	Fertilizer treatment				CV(%)
		NPK+FL	-PK+N+FL	-PK+N+fl	-PK+n+fl	
No. 2 ns	47-52	0.11	0.52	0.94	0.34	97.53
No. 3 ns	>52-57	5.93	7.00	7.18	6.67	58.50
No. 4 ns	>57-60	13.66	15.62	18.19	13.93	35.94
No. 5 ns	>60-65	39.56	49.31	43.05	46.12	19.49
No. 6 ns	>65-70	14.45	15.87	12.42	14.58	31.94
No. 7 ns	>70-75	1.42	1.00	1.83	1.10	70.07

ns = non significant

In August and September 2008, the status of Fe, Mn, Cu, Zn and B in the third fully mature leaves of mandarin twigs without flower and fruit bearing from the fourth treatment were investigated. The average concentration of each trace element in the leaves indicated that after four times foliar spraying of Zn the concentration of Zn was very high (Table 6). These data confirmed that the trace element spraying used in treatment 3 and 4 was sufficient to solve the problem of Zn deficiency.

Table 6. Optimum levels and average concentrations of trace elements in the index leaf samples from the fourth treatment.

Trace elements	Average concentration of trace elements (mg/kg)		
	Optimum levels	30-Aug-08	30-Sep-08
Fe	60-120*	118	121
Mn	25-100	69	91
Cu	5-16	5	7
Zn	25-100	348	552
B	36-100	55	71

*source: World Fertilizer Use Manual (1992)

The relative cost of input of fertilizer and relative mandarin total fruit yield were shown in Table 7.

By farmer fertilizer application rate the total cost of inputs was 72,546 baht/ha in which the fruit yield of 25,436 kg/ha was obtained. If P and K fertilizers were omitted, the cost of fertilizer applied to soil about 7,684 baht/ha was needed instead of 49,286 baht/ha as used by farmer. The foliar fertilizer application based on leaf analysis data required the input cost of 825 baht/ha while that by farmer practice needed about 23,260 baht/ha. Application of N fertilizer by consideration of N removal by fruit yield plus additional N to compensate N lost by leaching needed the cost of 1,100 baht/ha only.

The application of fertilizer according to Tr.2 (-PK+N+FL), Tr.3 (-PK+N+fl), and Tr.4 (-PK+n+fl) could reduce the fertilizer input cost about 57 88 and 97% compared to farmer practice (Tr.1). Though a lower cost of input were used in Tr.2, 3 and 4, the total fruit yield was not reduced but increased about 18 11 and 11 percent of that from Tr.1.

Table 7. Relative cost of input on fertilizers and mandarin fruit yield among different fertilizer treatments.

Item	Fertilizer treatment			
	NPK+FL	-PK+N+FL	-PK+N+fl	-PK+n+fl
Cost of input (baht/ha)				
Soil fertilizer	49,286.25	7,683.75	7,683.75	1,100.25
Foliar fertilizer	23,260.50	23,260.50	825.00	825.00
Total fertilizer	72,546.75	30,944.25	8,508.75	1,925.25
Relative total cost of input	100	42.65	11.73	2.63
Cost reduction (%)		57.35	88.27	97.37
Fruit yield (kg/ha)	25,346.00	30,105.00	28,114.00	27,945
Relative yield (%)	100	118	111	110

DISCUSSION

In this study, the application of only N fertilizer at the farmer rate to the mandarin trees grown in the soil rich in available P and exchangeable K did not reduce the total mandarin fruit yield compared to the farmer rate in which N, P and K were applied suggesting that in such soil condition there is no need to apply P and K fertilizer. Furthermore reduction of fertilizer usage by foliar spraying, by consideration of the need from leaf analysis instead of spraying program of farmer practice, did not reduce fruit yield and fruit qualities confirming the report of Kaosumain et

al. (2002) who indicated that leaf analysis could be used for fertilizer management. The pattern of the response of mandarin trees to the fertilizer treatments in this study agreed with the reports of Chanvichit et al. (2008), who found that fertilizer management following the result of soil analysis could yield the same amount and quality of mandarin as in the case of farmer's practice.

Since in this study fertilizer application according to Tr.3 (-PK+N+fl) and Tr.4 (-PK+n+fl) could reduce the cost of inputs of fertilizer by about 88 and 97% of that by farmer practice without yield reduction. We therefore recommended that in an orchard with high levels of available P and exchangeable K in the soil, and the mandarin trees were healthy the application of P and K fertilizer were not needed. Regarding the N application rate, in this study, the fertilizer trial did not start at the beginning of the season thus, the actual N requirement for mandarin fruit crop throughout the growing season could not be recommended. However, according to Supakamnerd et al. (2005) 1 kg of mandarin fruit at 10 months contained 1.44 g N, 0.39 g P_2O_5 and 2.09 g K_2O. This information could be used together with the soil analysis data on available P and exchangeable K in order to recommend of the proper application rates of N, P and K for mandarin fruit production of the farmer. At present the information on nutrient lost from leaching in Thailand, particularly the mandarin cultivated area in Chiang Mai, was not available. In this study, we assumed that the N lost by leaching was 40%, but the N lost in fact might vary with topography, climate and soil condition. Nevertheless, the obtained experimental results showed that the fertilizer application for mandarin orchards could be reduced without fruit yield declination.

CONCLUSION

From this study we could conclude that in soils with higher levels of available P (>60 mgP/kg) and exchangeable K (>120 mgK/kg) than the optimum level, no P and K fertilizer applications were needed for healthy mandarin trees. The foliar fertilizer application to mandarin trees could be managed by following the result of leaf analysis data. The amount of N application rate could be estimated by consideration of the N removal by expected fruit yield.

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