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Study on NPK Fertilizer Rate on Flowering and Yield of Longan (*Dimocarpus longan* Lour.) in Chanthaburi Province

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Application of NPK fertilizer is necessary for longan production as large amount of nutrients are depleted from soil by crop removal. The aim of the study was to examine effect of NPK fertilizer's rates on longan's growth, flowering and yield. The field experiment was conducted in Chanthaburi province, in South-East of Thailand. The treatments consisted of (1) control; (2) NPK at Longan Research and Development Center (LRDC)'s rate; (3) ½xN of LRDC's rate; (4) 2xN of LRDC's rate; (5) 4xN of LRDC's rate; (6)½xP of LRDC's rate; (7) 2xP of LRDC's rate; (8) 4xP of LRDC's rate; (9) ½xK of LRDC's rate; (10) 2xK of LRDC's rate; (11) 4xK of LRDC's rate; and (12) farmer's rate, in a RBCD with 3 replications. Twenty-five branches were randomly labeled at the start of the experiment for parameter measurements. Leaf width, leaf length, fresh leaf weight and concentrations of N, P and K were determined before flower stimulation. After flower stimulation, percentage of flowering, fruit width, fruit length, average weight per fruit, fruit weight per bouquet, seed width and thickness of pulp were collected. The results showed that decrease N or K fertilizer to ½times of LRDC's rate resulted of late flowering, in which those 2 treatments showed a trend of lower flowering than the other treatments, since 30 days after $KClO_3$ application. Leaf length increased with increasing N fertilizer to 4-times of LRDC's rate while increasing N fertilizer to 2- and 4-times of LRDC's rate, it decreased fruit size. Moreover, increasing N fertilizer up to 4-times of LRDC's rate, it decreased the average weight per fruit, seed width and thickness of pulp. However, altering N fertilizer did not affect leaf width, fresh leaf weight, foliar of N, P and K concentrations, and fruit weight per bouquet. Application of P fertilizer at either ½- or 2-times of LRDC's rate decreased fruit size. But altering P fertilizer rates did not affect leaf growth, seed width and thickness of pulp. Decrease K fertilizer to ½times of LRDC's rate decreased fruit size, average weight per fruit and thickness of pulp but altering K fertilizer rates did not affect leaf growth and seed width. Application of NPK at the farmer's rate resulted of a longer leaf than LRDC's rate did but it has a lower average weight per fruit than LRDC's rate. It should be concluded that (1) high rate of N fertilizer (4-times) increased leaf length but decreased fruit size and weight; (2) decrease K fertilizer (½-times) decreased fruit size and weight; and (3) LRDC's recommend rate should be adopted for longan production at particular study site.

Keywords: Chanthaburi, longan, NPK fertilizer

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Introduction

Longan is one of the most economic fruits and is widely grown in many parts of Thailand. Longan produced in Chanthaburi province has been exported and received enormous income of 8,100 million baht in 2013, moreover in 2014, the income has been rised to 9,600 million baht (Office of Agricultural Economics, 2014). Even the large area for longan production mostly located in North of Thailand with 800,000 rai though Chanthaburi province has produced more intensive yield per rai than those grown in North of Thailand (Office of Agricultural Economics, 2014). Large amount of nutrients and very expensive management are concerned for the intensive off-season longan production. Nitrogen is necessary for plant metabolism as N is an integral part of protein development and chloroplast structure and function. However, if large proportion of N is applied, a negative effect may occur (Barker and Bryson, 2007). There is some publised researchs on increasing effective longan production such as Khaosumain *et al*. (2013) who studied nutrient requirements using for longan flushing and crop removal in North of Thailand. They recommended NPK fertilizer rate which depend upon yield in previous crop and canopy size. Unfortunately, those experiments were conducted in North of Thailand, so, it is necessary to bring the recommendation rate from this useful information to adapt for longan production in the different geography.

Objectives: To examine effect of NPK fertilizer rate on flowering and yield of longan in Chanthaburi province, Thailand.

Materials and methods

Field experiment was conducted in Thamai District, Chanthaburi Province, Thailand on 5 years-old longan 'Daw' variety with canopies of 3.8 metres diameter. A randomized complete block design with 3 replications was applied. The treatments consisted of :(T1) control, (T2) NPK at Longan Research and Development Center (LRDC)'s rate (364:88:400; N:P_2O_5:K_2O), (T3) ½xN of LRDC's rate (183:88:400; N:P_2O_5:K_2O), (T4) 2xN of LRDC's rate (728:88:400; N:P_2O_5:K_2O), (T5) 4xN of LRDC's rate (1,456:88:400; N:P_2O_5:K_2O),(T6) ½xP of LRDC's rate (364:44:400; N:P_2O_5:K_2O), (T7) 2xP of LRDC's rate (364:176:400; N:P_2O_5:K_2O), (T8) 4xP of LRDC's rate (364:352:400; N:P_2O_5:K_2O), (T9) ½xK of LRDC's rate (364:88:200; N:P_2O_5:K_2O), (T10) 2xK of LRDC's rate (364:88:800; N:P_2O_5:K_2O),(T11) 4xK of LRDC's rate (364:88:1,600; N:P_2O_5:K_2O) and (T12) farmer's rate (364:176:400; N:P_2O_5:K_2O). The fertilizers were broadcasted by hand under each canopy using 46-0-0, 15-15-15 and 0-0-60 by weight according to the

treatment. All the fallen leaves under the canopy were removed prior to the application of Potassium Chlorate ($KClO_3$) at 250 g/tree on 7th September 2014. The soil chemical property is shown in Table 1. Twenty five branches were randomly labeled at the start of the experiment. Data collection before stimulating longan flowering (July-August 2014) on the labeled branches included leaf width, leaf length, fresh leaf weight and concentration of N (Kjeldhal method by Bremner and Keeny, 1982), P (nitric-perchloric acid digestion and determination by yellow molybdate method by Murphy and Riley, 1962) and K (atomic absorption spectrophotometry, Jackson and Mahmood, 1994) on acid digested dried leaf material. After stimulating longan flowering , percentage of flowering , fruit width, fruit length, fresh fruit weight, thickness of pulp, seed width were collected at harvest on 10th April 2015.

Table 1 Soil chemical properties

Property	**Value**
Soil texture [1/]	Sandy clay loam
pH [2/]	4.0
Organic Matter [3/] (%)	2.12
E.C.[4/] (dS/m)	1.31
Bray II extractable P [5/] (mg kg^{-1})	6.12
Exchangeable K [6/] (mg kg^{-1})	29.5
Exchangeable Ca [6/] (mg kg^{-1})	92.9
Exchangeable Mg [6/] (mg kg^{-1})	14.9

[1/] Hydrometer (Attananda and Chancharoensuk, 1999) [2/] 1:1 soil:water (Attananda and Chancharoensuk, 1999) ; [3/] Walkley & Black (Attananda and Chancharoensuk, 1999) ; [4/] Soil saturation (Attananda and Chancharoensuk, 1999) ; [5/] Bray II method (Attananda and Chancharoensuk, 1999) ; [6/] extraction by 1 *N* NH_4OAc analyse by Atomic Absorption Spectrophotometer (Attananda and Chancharoensuk, 1999)

Results

Leaf Growth

Leaf size and weight

Leaf width and weight were not affected by rate of NPK fertilizer (Fig.1A, 1C) whereas leaf length showed different result. (Fig.1B). Increase N fertilizer to 4-times of LRDC's rate (T5) increased leaf length whereas application of N fertilizer at either ½-times (T3) or 2-times of LRDC's rate showed no effect. However, it was found that application of N fertilizer at either ½-times (T3) or 4-times (T5) showed longer leaf than application of LRDC's rate (T2).

Altering P or K fertilizer rates (T6-T11) showed no significant effect on leaf growth, additionally, T6-T11 showed no significant difference on leaf length compared to LRDC's rate.

Application of NPK at farmer's rate (T12) showed no significant difference on leaf growth compared to control.

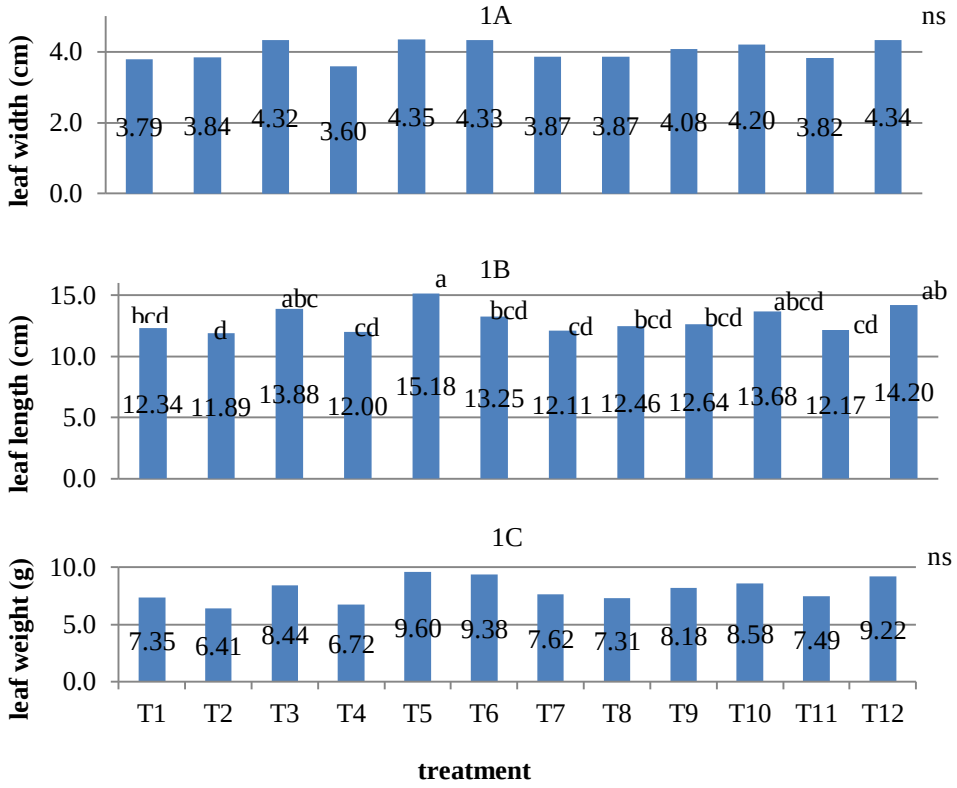


Fig.1. Leaf width (Fig.1A), length (Fig.1B) and weight (Fig.1C) at maturity stage before flower stimulation where; T1:control, T2:NPK at LRDC's rate (364:88:400; N:P_2O_5:K_2O), T3:½xN LRDC's (183:88:400; N:P_2O_5:K_2O), T4:2xN LRDC's rate (728:88:400; N:P_2O_5:K_2O), T5:4xN LRDC's rate (1456:88:400; N:$_2O_5$:K_2O), T6:½xP LRDC's rate (364:44:400; N:P_2O_5:K_2O), T7:2xP LRDC's rate (364:176:400; N:P_2O_5:K_2O), T8:4xP LRDC's rate (364:352:400; N:P_2O_5:K_2O), T9:½xK LRDC's rate (364:88:200; N:P_2O_5:K_2O), T10:2xK LRDC's rate (364:88:800; N:P_2O_5:K_2O), T11:4xK LRDC's rate (364:88:1600; N:P_2O_5:K_2O), and T12:farmer's rate (364:176:400; N:P_2O_5:K_2O plus micronutrients). Non significant results (ns) refer to the treatments which showed non statistical difference using DMRT at $p \geqslant 0.05$. Different letters above columns indicate significant difference in each parameter. CV% of Figs 1A, 1B and 1C were 8.19, 7.64 and 16.81% respectively.

Leaf N, P and K concentration

Leaf N, P and K concentrations were not affected by altering NPK fertilizer rates (T3-T11) (Figs 2A, 2B, 2C). Moreover, application of NPK at farmer's rate (T12) showed no significant difference on leaf N, P and K concentrations compared to control (T1) and LRDC's rate (T2).

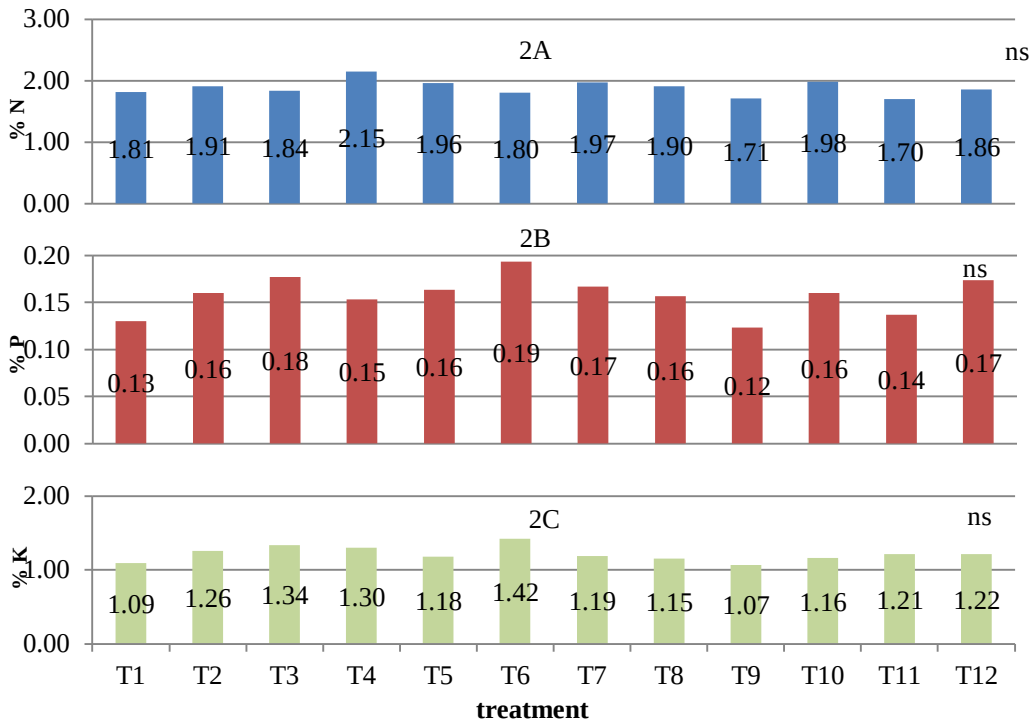


Fig.2. N (Fig.2A), P (Fig.2B) and K (Fig.2C) concentrations in foliage prior to longan flower stimulation. See Fig.1 for captions. CV% of Figs 2A, 2B and 2C were 15.3, 28.3 and 22.1%, respectively.

Percentage of flowering

Percentage of flowering at 30, 35, 40 days after applying $KClO_3$**,** and total flowering were not affected by altering NPK fertilizer rates (T3-T11) (Table 2). Moreover application of NPK at farmer's rate (T12) showed no significant difference on percentage of flowering at 4 periods compared to control (T1) and LRDC's rate (T2). However, at 45 days after applying $KClO_3$ decrease N or K fertilizer to ½-times of LRDC's rate (T3, T9) resulted of high percentage of flowering (9.69-10.8%) while the treatments which had low percentage of flowering varied from 0 to 3.51% .

Yield

Fruit size

Increase N fertilizer to 2 and 4-times of LRDC's rate (T4, T5) decreased fruit size (Figs 3A, 3B). Additionally, application of P fertilizer at either ½-times or 2-times of LRDC's rate (T6, T7) decreased fruit size. Moreover,

decrease K fertilizer to ½-times of LRDC's rate (T9) decreased fruit size. Whereas application of NPK at farmer's rate (T12) showed no significant difference on fruit size compared to control and LRDC's rate.

Fruit weight

Fruit weight per bouquet was not affected by altering rate of NPK fertilizer (Fig.4A) whereas the average weight per fruit showed a different result (Fig.4B). Increase N fertilizer to 4-times of LRDC's rate (T5) decreased the average weight per fruit whereas application of N fertilizer at either ½-times or 2-times (T3, T4) showed no effect. Moreover, it was found that decrease K fertilizer to ½-times of LRDC's rate (T9) decreased the average weight per fruit. Application of NPK at farmer's rate (T12) showed no significant difference on fruit weight compared to control. However, T12 resulted of less average weight per fruit than LRDC's rate did.

Seed width and thickness of pulp

Increase N fertilizer to 4-times of LRDC's rate (T5) decreased seed width and thickness of pulp whereas application of N fertilizer at ½-times or 2-times of LRDC's rate (T3, T4) showed no effect (Fig.5A, 5B). Altering P or K fertilizer rates (T6-T11) showed no significant effect on seed width. Altering P fertilizer rates (T6-T8) showed no significant effect on thickness of pulp. But decrease K fertilizer to ½-times of LRDC's rate (T9) decreased thickness of pulp whereas application of K fertilizer at 2-and 4-times of LRDC' rate (T10, T11) showed no effect. Application of NPK fertilizer at farmer's rate (T12) showed no significant difference on seed width and thickness of pulp compared to control and LRDC's rate.

Discussions

Soil properties

The field experiment had acidic soil with pH 4.0 which is below the recommended range (5.5-6.5) for longan orchard, moreover, extractable K, Ca and Mg were lower than the recommended ranges which are 100-200, 800-1500 and 250-450 mg/kg for K, Ca and Mg, respectively (Khaosumain *et al*., 2013). It was observed that the marginally low leaf phosphorus (minimum of 0.12%P as the mature leaf should contain 0.12-0.22%P) may cause of acidic soil which reduced availability of P uptake (Uexkull and Mutert, 1995)

Table 2 Percentage of flowering among 4 time peroids

Treatment	Percentage of flowering(%)				
	30 days after applying	35 days after applying	40 days after applying	45 days after applying	Total flowering*

	$KClO_3$	$KClO_3$	$KClO_3$	$KClO_3$	
T 1	77.92^{ns}	10.30^{ns}	6.37^{ns}	2.10^{bc}	96.69^{ns}
T 2	69.08	10.73	15.06	1.11^{bc}	95.98
T 3	58.11	17.59	9.11	9.69^{a}	94.50
T 4	69.38	6.59	13.58	5.48^{abc}	95.04
T 5	70.54	17.50	4.85	3.11^{bc}	95.99
T 6	60.19	22.59	11.81	1.55^{bc}	96.15
T 7	68.22	11.33	8.26	3.12^{bc}	90.94
T 8	64.62	15.03	10.64	3.51^{bc}	93.80
T 9	54.32	9.50	18.52	10.81^{a}	93.15
T 10	66.61	11.54	7.47	7.04^{ab}	92.66
T 11	75.94	11.76	3.88	3.10^{bc}	94.68
T 12	73.41	12.58	9.14	0^{c}	95.14
CV%	20.59	74.16	78.98	75.53	3.76

*calculate from the accumulation percentage of flowering among 4 periods (30, 35, 40 and 45 days after applying $KClO_3$). Non significant results (ns) refer to the treatments which showed non statistical difference using DMRT at $p \geqslant 0.05$. Different letters above number indicate significant difference.

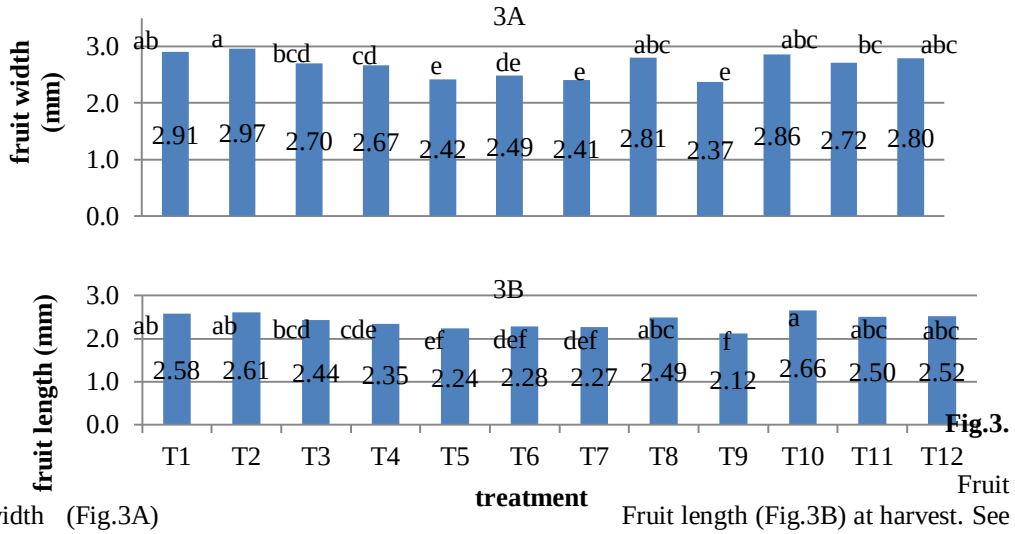
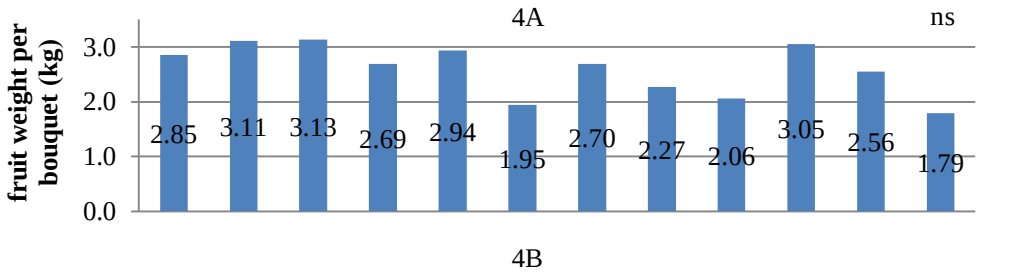


Fig.3. Fruit width (Fig.3A) Fruit length (Fig.3B) at harvest. See fig.1 for captions. CV% of Figs 3A, 3B were 4.41 and 3.92%, respectively.



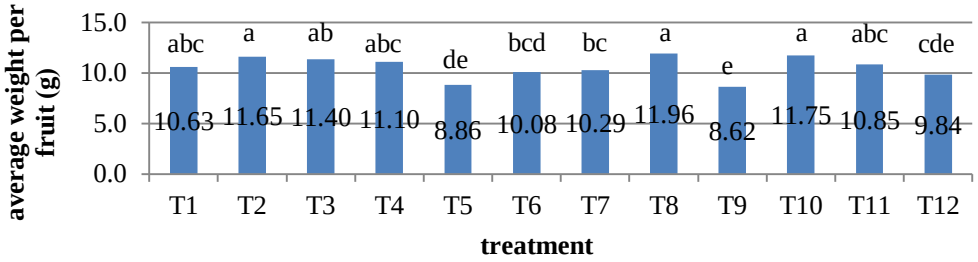


Fig.4 Fruit weight per bouquet (Fig.4A) and average weight per fruit (Fig.4B) at harvest. See Fig.1 for caption. CV% of Figs 4A and 4B were 29.71 and 6.78%, respectively.

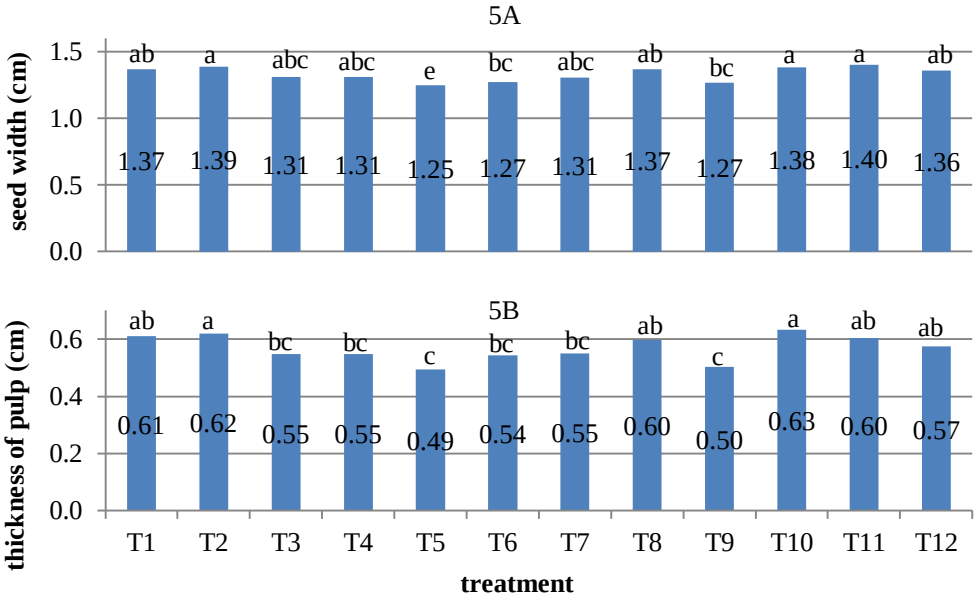


Fig.5. Seed width (Fig.5A) and thickness of pulp (Fig.5B) at harvest. CV% of Figs 5A and 5B were 4.12 and 5.55%, respectively.

Leaf growth and flowering

Increase N fertilizer increased leaf length as N supply is a major constitution in leaf for photosynthesis (Sham *et al*., 2005). The result is similar with Vos (1998) who found that potato leaf size increased with increasing N fertilizer rate up to 2000 mg. N per pot, but unfortunately, this study did not report yields.

Decrease N or K fertilizer to ½-times of LRDC's rate (T3, T9) resulted of late flowering as shown at 45 days after applying $KClO_3$ in which T3 and T9 showed a trend of less flowering than the other treatment since 30 days after

applying $KClO_3$. It may be described that N and K are required in the large amount for longan production (Khaosumain *et al*., 2013) as N is an integral part of chlorophyll manufacture through photosynthesis, stimulates green leaf growth and promotes fruit and seed development (Smith, 2015). Moreover, K is essential for photosynthesis and regulates many metabolic processes required for growth, fruit and seed development. Receiving insufficient N or K fertilizers at specific period may limit longan flowering or result of delay flowering.

Yield

Application of N fertilizer enhance leaf length but if excessive supply it may lead to a negative effect (Barker and Bryson, 2007) due Tayler *et al.* (1975) suggested that N assimilation uses carbohydrates for carbon skeleton and energy supply hence if receive excessive N, plant may enlarge leaf size but reduce total non carbohydrate (TNC) which in turn limiting TNC translocation to fruit biomass (Xia and Cheng, 2004). Our finding is similar with Khaosumain *et al.* (2010)'s report which found that fruit size and dry weight of fruit started to decrease when N fertilizer at 160 g/tree were applied.

It was found that decrease K fertilizer to ½-times of LRDC's rate (T9) decreased the average weight per fruit. It can be explained that longan needs much of K fertilizer for accumulating sugar and enlarge size of fruit (Khaosumain *et al*., 2013), additionally, Ungasit *et al.* (1999) reported that longan require N and P at early stages of development but K is required at the stages of fruit filling. Then decreasing K fertilizer may cause reduction of longan size.

This experiment did not focus on micronutrients effect but it seems that NPK application by farmer rate (T12) which contains micronutrients resulted of longer leaf and bigger fruit size than application of NPK alone (T7: 2-times P of LRDC's rate). This could be explained that firstly, acidic effect of soil reduced phosphorus availability even large amount of P fertilizer were applied. And secondly, micronutrients are essential for plant growth including longan which needs zinc, boron, iron, manganese and copper (Menzel et al., 1992) but time and rate of micronutrients have not yet been studied. Further reserch should focus on the effect of micronutrients on yield and quality of longan for plenary off-season longan production.

It should be concluded that (1) high rate of N fertilizer (4-times) increased leaf length but decreased fruit size and weight; (2) decrease K fertilizer (½-times) decreased fruit size and weight; and (3) LRDC's

recommend rate should be adopted for longan production at particular study site.

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