CHAPTER 4

RESULT AND DISCUSSION

The effects of the cultural practices, lime and organic/inorganic fertilizer applications including foliar-Zn spray on soil properties, nutrients availability, crop growth and yield are presented as the following results.

4.1 Soil physical properties

The effects of the studied treatments on soil physical properties of 0-20 cm soil depth, bulk density (BD), field capacity (FC), particle density (PD), total porosity (TP), and aeration porosity (AP) at different times of soil sampling during crop growing periods are shown in Table 4.1.1 and Figures 4.1.1-4.1.2. The effect of foliar Zn spray on soil physical properties are not presented in this result, because soil sampling for statistical analysis of soil physical properties under the effects of foliar Zn application were not conducted.

Table 4.1.1 indicates that BD, FC, TP and AP under conventional planting (CP) were not significantly different from those under furrow cultivation (CF). However, the studied soil physical properties under CF tended to be better than those under CP. The BD mean values under CF, 1.25 and 1.18 Mg m^{-3} were significantly lower than those under CP, 1.32 and 1.26 Mg m^{-3} on 22nd August, 2009 and 17th September, 2010 respectively at the beginning of the trial during the mid rainy season, The AP-mean value in CF plot, 0.13 m^3m^{-3} was also significantly higher than that in CP plot, 0.10 m^3m^{-3}, at the beginning of the experiment on22nd August, 2009. These might be due to soil loss and runoff including rainfall energy impacts occurring in CF plot less than in CP plot, particularly at beginning of rainy season. Moreover, the accumulations of plant and root residues under CF were higher than those under CP, which could induce better soil structure formation, giving higher values of TP and AP in CF plot than in CP plot (Table 4.1.1 and Figure 4.1.1).

These results indicated furrow cultivation (CF) could harvest higher amount of rain water due to the looser top soil layer with lower BD and higher AP values, leading to higher rate of infiltration with higher accession of rain water into the soil profile, resulting in higher amount of stored soil water (data are not presented due to randomly measured without statistical analysis), better crop development and crop yields, compared to conventional planting (CP). Moreover, the accumulations of plant and root residues under CF were higher than those under CP, which could induce better soil structure formation, giving higher values of TP and AP in CF plot than in CP plot (Figure 4.1.1).

Mean values of BD, FC, TP, and AP were not significantly different under Control (average of CP and CF only), application of lime (L), organic and inorganic fertilizers (OF and IF). However, OF tended to give the highest FC value at beginning and middle of lablab bean growing in the 2nd year of experimental (17 September, 2010 and 19 November, 2010) compared L, Control and IF which gave the 2nd, 3rd and 4th high value of FC respectively (Table 4.1.1 and Figure 4.1.2). These might be caused by the effects of organic matter on soil aggregate stability and better soil structure formation thereby improves water holding capacity (FAO, 2005).

Table 4.1.1 *Variations of Bulk Density (BD), Field Capacity (FC), Total Porosity (TP), and Aeration Porosity (AP) within 0-20 cm depth affected by conventional planting (CP), furrow cultivation (CF), applications of lime (L), organic (OF)/inorganic (IF) fertilizers and Control (average of CP and CF only) at different times of lablab bean growing during August, 2009- January, 2011.*

Date of Sampling	Soil Physical properties	Cultural Practices		LSD-1 P<0.05	Lime and fertilizer applications				LSD-2 P<0.05
		CP	CF		Control	L	OF	IF	
22-Aug-2009	**BD (Mg m^{-3})**	1.32a	1.25b	**0.06**	-	-	-	-	-
	FC (m^3 m^{-3})	0.35	0.33	**ns**	-	-	-	-	-
	TP (m^3 m^{-3})	0.45	0.46	**ns**	-	-	-	-	-
	AP (m^3 m^{-3})	0.10b	0.13a	**0.03**	-	-	-	-	-
15 –Nov-2009	**BD (Mg m^{-3})**	1.27	1.27	**ns**	1.3	1.29	1.25	1.25	**ns**
	FC (m^3 m^{-3})	0.35	0.36	**ns**	0.34	0.37	0.35	0.37	**ns**
	TP (m^3 m^{-3})	0.46	0.45	**ns**	0.45	0.44	0.47	0.46	**ns**
	AP (m^3 m^{-3})	0.10	0.09	**ns**	0.11	0.07	0.12	0.09	**ns**
20- Feb-2010	**BD (Mg m^{-3})**	1.26	1.24	**ns**	1.28	1.26	1.26	1.21	**ns**
	FC (m^3 m^{-3})	0.32	0.35	**ns**	0.33	0.33	0.35	0.35	**ns**
	TP (m^3 m^{-3})	0.45	0.45	**ns**	0.44	0.45	0.46	0.47	**ns**
	AP (m^3 m^{-3})	0.09	0.11	**ns**	0.10	0.12	0.11	0.12	**ns**
17 –Sep-2010	**BD (Mg m^{-3})**	1.26a	1.18b	**0.07**	1.25	1.19	1.2	1.24	**ns**
	FC (m^3 m^{-3})	0.35	0.37	**ns**	0.36	0.37	0.38	0.33	**ns**
	TP (m^3 m^{-3})	0.46	0.49	**ns**	0.46	0.49	0.48	0.47	**ns**
	AP (m^3 m^{-3})	0.11	0.12	**ns**	0.10	0.12	0.10	0.13	**ns**
19- Nov-2010	**BD (Mg m^{-3})**	1.27	1.20	**ns**	1.27a	1.23ab	1.17b	1.27a	**0.08**
	FC (m^3 m^{-3})	0.35	0.36	**ns**	0.34	0.35	0.38	0.33	**ns**
	TP (m^3 m^{-3})	0.45	0.48	**ns**	0.46	0.47	0.48	0.45	**ns**
	AP (m^3 m^{-3})	0.10	0.12	**ns**	0.12	0.12	0.10	0.12	**ns**
14 –Jan-2011	**BD (Mg m^{-3})**	1.29	1.22	**ns**	1.29	1.26	1.23	1.23	**ns**
	FC (m^3 m^{-3})	0.34	0.36	**ns**	0.35	0.35	0.35	0.36	**ns**
	TP (m^3 m^{-3})	0.44	0.47	**ns**	0.44	0.45	0.46	0.47	**ns**
	AP (m^3 m^{-3})	0.09	0.11	**ns**	0.09	0.09	0.11	0.11	**ns**

LSD-1 and LSD-2 are the least significant differences of the means caused by different cultivation practices, applications of lime, organic and inorganic fertilizers respectively, for comparison at $P < 0.05$, a and b represent differences between the means,

ns : is none significant differences of the means.

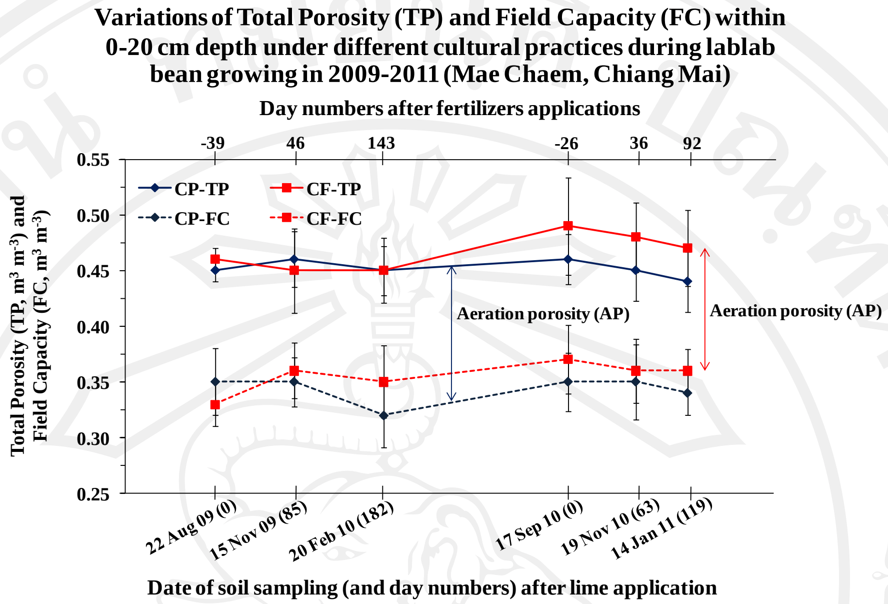


Figure 4.1.1 *Variations of total porosity (TP), field capacity (FC) and aeration porosity (AP) under conventional planting (CP) and furrow cultivation (CF) at different time of lablab bean growing during August, 2009- January, 2011*

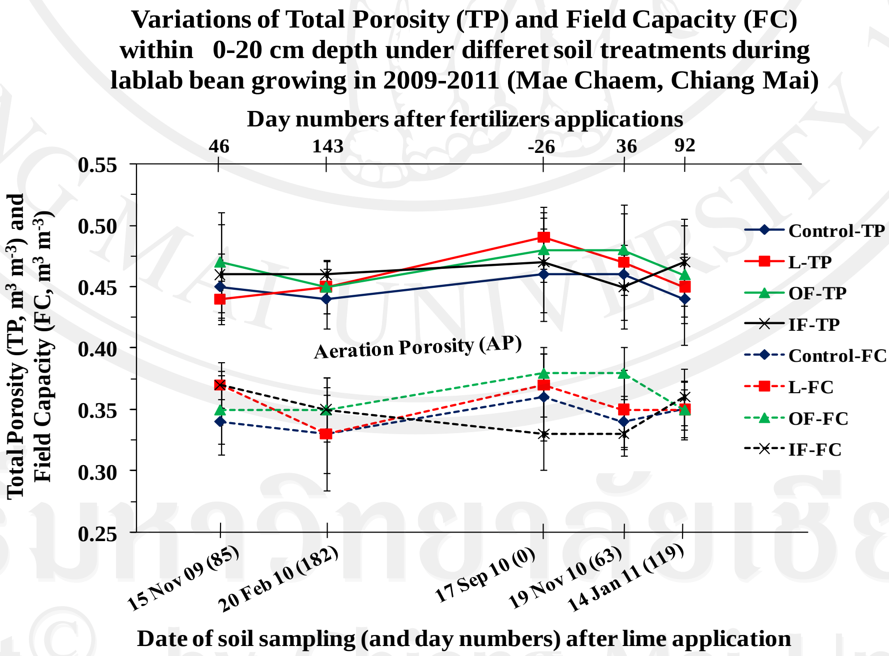


Figure 4.1.2 *Variations of total porosity (TP), field capacity (FC) and aeration porosity (AP) under Control (average of CP and CF only), applying lime (L), organic fertilizer (OF) and inorganic fertilizer (IF) at different time of lablab bean growing during August, 2009- January, 2011*

4.2 Soil chemical properties

The results of soil reaction (pH), organic matter content (OM), extractable phosphorus (Ext.P) and extractable zinc (Ext. Zn) within 0-20 and 20-40 cm soil depth as affected by conventional planting, furrow cultivation, lime, organic/inorganic fertilizers and foliar zinc and no zinc applications are presented in Table 4.2.1- 4.2.4 and Figure 4.2.1- 4.2.9.

4.2.1 Soil reaction (soil pH)

After applying lime and fertilizers under conventional planting (CP) and furrow cultivation (CF), CF significantly gave higher pH values of both topsoil (0-20 cm) and subsoil (20-40 cm) layers than CP throughout the 2 experimental years (Tables 4.2.1a-b and Figures 4.2.1a-b). In the 1st experimental year during 22nd August, 2009 – 20th February, 2010, both CF and CP tended to increase the topsoil (0-20 cm) pH values which varied from 4.56 to 4.69 under CF and from 4.03 to 4.28 under CP (Table 4.2.1a and Figure 4.2.1a). The pH of the subsoil layer (20-40 cm) in CP plot also tended to be increased from 3.94 to 4.12, whilst the pH in CF plot tended to be decreased from 4.41 to 4.26 (Table 4.2.1b Figure 4.2.1a). However, the pH of both topsoil and subsoil layers under both CP and CF tended to be unchanged during the 2nd experimental year, from 17th September, 2010 to 14th January, 2011 (Figure 4.2.1b). These might be caused by the interaction effects of furrow cultivation with soil amendments, lime and fertilizers applications which were better maintained under CF than those under CP.

Liming (L) significantly gave the highest soil pH in both top-soil (0-20 cm) and sub-soil (20-40 cm) almost throughout the experimental periods, particularly during the 2nd year-experiment, when compared to organic fertilizer (OF), inorganic fertilizer (IF) and Control (average of CP and CF only), which gave the soil pH values similarly (Table 4.2.1a-b and Figure 4.2.2a-b). The highest value of the topsoil (0-20 cm) pH under liming was 4.81 in the 1st year (September, 2009) and 5.47 in the 2nd year (November, 2010) (Table 4.2.1a and Figure 4.2.2a-b). The lowest pH values of topsoil were found under Control (average CP and CF only) compared to either liming (L) or fertilizer applications (OF/IF) throughout the 1st year experiment (August, 2009 – February, 2010) (Figure 4.2.2a). Control gave the lowest pH values at 4.12 and 4.17 in December, 2009 and 2010 respectively (Figure 4.2.2a-b). The pH values under Control, OF and IF were not different during the 2nd experimental year, September, 2010 – January, 2011. Variations of subsoil-pH values under the single effect of different treatments (L, OF and IF) were rather high during the 1st year trial (August, 2009 – February, 2010) (Figure 4.2.3a), whilst, the pH variations during the 2nd year trial were rather consistent or unchanged in both topsoil and subsoil layers (Figures 4.2.2b and 4.2.3b).

Most soil pH level were not optimum for increasing the availability of plant nutrients. Therefore, lime was applied in the 2nd year before planting lablab bean in September 2010. The topsoil pH were raised to 5.47 and 5.03 after 63 and 119 days of lime applications respectively (Table 4.2.1a and Figure 4.2.2b). The increased soil pH caused by liming in the topsoil (from the 1st and the 2nd liming), the amount of lime and times of lime reaction was sufficient to raise the soil pH in the 2nd year. Applying fertilizers in both experimental years had the short term effects on soil pH increasing. Soil pH decreasing had been found after applying fertilizers for several weeks. This might be caused by residual effects of phosphate fertilizer which might be oxidized and gave H^+ after nitrification according to the following soil chemical reaction of phosphate fertilizer.

$$NH_4H_2PO_4 + O_2 \longrightarrow 2H^+ + NO_3^- + H_2PO_4^- + H_2O$$

This was supported by Halvin et al. (1999) who found that phosphoric acid ($H_3PO_4^-$) given by dissolving phosphorus fertilizer could reduce the pH of solution to 1.5. In addition, crop removal of exchangeable cations with exchangeable H^+ and the decomposition of organic materials could induce substantially soil acidity, by decreasing the soil pH.

The results indicated that liming was the best practice to improve soil pH within both topsoil and subsoil layers. Soil pH within subsoil was raised from 4.18 at the beginning to be 4.24 at the end of experimental period by liming (Table 4.2.1b and Figure 4.2.3). However, soil pH within both topsoil and subsoil under all soil treatments during the 1st year trial were largely fluctuated (Figures 4.2.2a and 4.2.3a). These might be caused by the effect of rain water, which dissolved lime and fertilizers to deeper soil depth, and might be caused by the decayed root of lablab bean.

Foliar zinc spraying (Zn_1) had no effect on pH values of neither topsoil (0-20 cm) nor subsoil (20-40 cm) during 19 November, 2010 – 14 January, 2011. The soil pH values under foliar zinc (Zn_1) and no zinc (Zn_0) application were not significantly different. The interaction effects among cultivation practices, lime, fertilizers and zinc application on soil reaction (pH) were not found at significant level.

Table 4.2.1a *Variations of mean values of soil pH within 0-20 cm depth under different treatments, cultivation methods (conventional planting, CP and furrow cultivation, CF, Control (average of CP and CF only), lime (L), organic (OF) and inorganic (IF) fertilizers, foliar zinc (Zn_1) and no-zinc (Zn_0) applications during August 2009- January 2011.*

Sampling date	Day numbers after			Cultivation Practices		LSD-1 (P<0.05)	Lime and fertilizers applications				LSD-2 (P<0.05)	Foliar-Zn spray		LSD-3 (P<0.05)
	liming	foliar-Zn, OF and IF applying	Lablab bean sowing	CP	CF		Control	L	OF	IF		Zn_1	Zn_0	
22-Aug-09	0	-39	-17	4.03b	4.56a	**0.27**	4.30	4.30	4.30	4.30	**ns**	**na**	**na**	**na**
30-Sep-09	39	0	23	4.25	4.62	**ns**	4.21b	4.81a	4.44b	4.29b	**0.35**	**na**	**na**	**na**
19-Oct-09	58	19	42	4.25b	4.62a	**0.35**	4.22b	4.74a	4.43b	4.37b	**0.25**	**na**	**na**	**na**
15-Nov-09	85	46	69	4.38b	4.58a	**0.17**	4.23c	4.60ab	4.39bc	4.71a	**0.27**	**na**	**na**	**na**
19-Dec-09	119	80	103	4.25	4.65	**ns**	4.17b	4.50a	4.47a	4.66a	**0.25**	**na**	**na**	**na**
23-Jan-10	154	115	138	4.26b	4.65a	**0.15**	4.25b	4.80a	4.35b	4.43b	**0.28**	**na**	**na**	**na**
20-Feb-10	182	143	166	4.28b	4.69a	**0.24**	4.26c	4.74a	4.53ab	4.44bc	**0.26**	**na**	**na**	**na**
17-Sep-10	0	-26	-12	4.28b	4.60a	**0.32**	4.23b	4.80a	4.40b	4.32b	**0.24**	**na**	**na**	**na**
19-Nov-10	63	36	52	4.35b	4.84a	**0.12**	4.37b	5.47a	4.39b	4.17c	**0.10**	4.61	4.59	**ns**
18-Dec-10	92	65	81	4.17b	4.62a	**0.03**	4.12b	5.09a	4.25b	4.09b	**0.28**	4.44a	4.34b	**0.08**
14-Jan-11	119	92	108	4.24	4.64	**ns**	4.29b	5.03a	4.31b	4.14c	**0.23**	4.46	4.42	**ns**

LSD-1, LSD-2 and LSD-3 are the least significant differences of the means, caused by different cultivation practices, applications of lime, organic/inorganic fertilizers and foliar zinc application respectively, for comparison at $P < 0.05$

a, b, and c represent differences between the means; ns : is none significant differences of the means. na: is not available

Table 4.2.1b *Variations of mean values of soil pH within 20-40 cm depth under different treatments, cultivation methods (conventional planting, CP and furrow cultivation, CF), Control (average of CP and CF only), lime (L), organic (OF) and inorganic (IF) fertilizers, foliar zinc (Zn_1) and no-zinc (Zn_0) applications during August, 2009- January, 2011.*

Sampling date	Day numbers after			Cultivation Practices		LSD-1 (P<0.05)	Lime and fertilizers applications				LSD-2 (P<0.05) CP	Foliar-Zn spray		LSD-3 (P<0.05)
	liming	foliar-Zn, OF and IF applying	Lablab bean sowing	CP	CF		Control	L	OF	IF		Zn_1	Zn_0	
22-Aug-09	0	-39	-17	3.94b	4.41a	**0.28**	4.18	4.18	4.18	4.18	**ns**	**na**	**na**	**na**
30-Sep-09	39	0	23	4.06	4.25	**ns**	4.11	4.25	4.11	4.15	**ns**	**na**	**na**	**na**
19-Oct-09	58	19	42	4.13	4.33	**ns**	4.11	4.28a	4.20ab	4.31a	**ns**	**na**	**na**	**na**
15-Nov-09	85	46	69	4.09b	4.29a	**0.15**	4.21a	4.24a	4.09b	4.24a	**0.09**	**na**	**na**	**na**
19-Dec-09	119	80	103	4.08b	4.25a	**0.10**	4.14	4.16	4.15	4.20	**ns**	**na**	**na**	**na**
23-Jan-10	154	115	138	4.09b	4.24a	**0.14**	4.04c	4.25a	4.24ab	4.15b	**0.09**	**na**	**na**	**na**
20-Feb-10	182	143	166	4.12	4.26	**ns**	4.13	4.24	4.21	4.16	**ns**	**na**	**na**	**na**
17-Sep-10	0	-26	-12	4.09	4.29	**ns**	4.11b	4.34a	4.11b	4.21ab	**0.18**	**na**	**na**	**na**
19-Nov-10	63	36	52	4.02b	4.24a	**0.04**	4.14ab	4.20a	4.10ab	4.09b	**0.10**	4.12	4.14	**ns**
18-Dec-10	92	65	81	4.05	4.28	**ns**	4.15	4.20	4.14	4.17	**ns**	4.18	4.24	**ns**
14-Jan-11	119	92	108	4.04b	4.28a	**0.14**	4.14b	4.24a	4.15ab	4.12b	**0.09**	4.18	4.13	**ns**

LSD-1, LSD-2 and LSD-3 are the least significant differences of the means, caused by different cultivation practices, applications of lime, organic/inorganic fertilizers and foliar zinc application respectively, for comparison at P < 0.05

a, b, and c represent differences between the means; ns : is none significant differences of the means. na: is not available

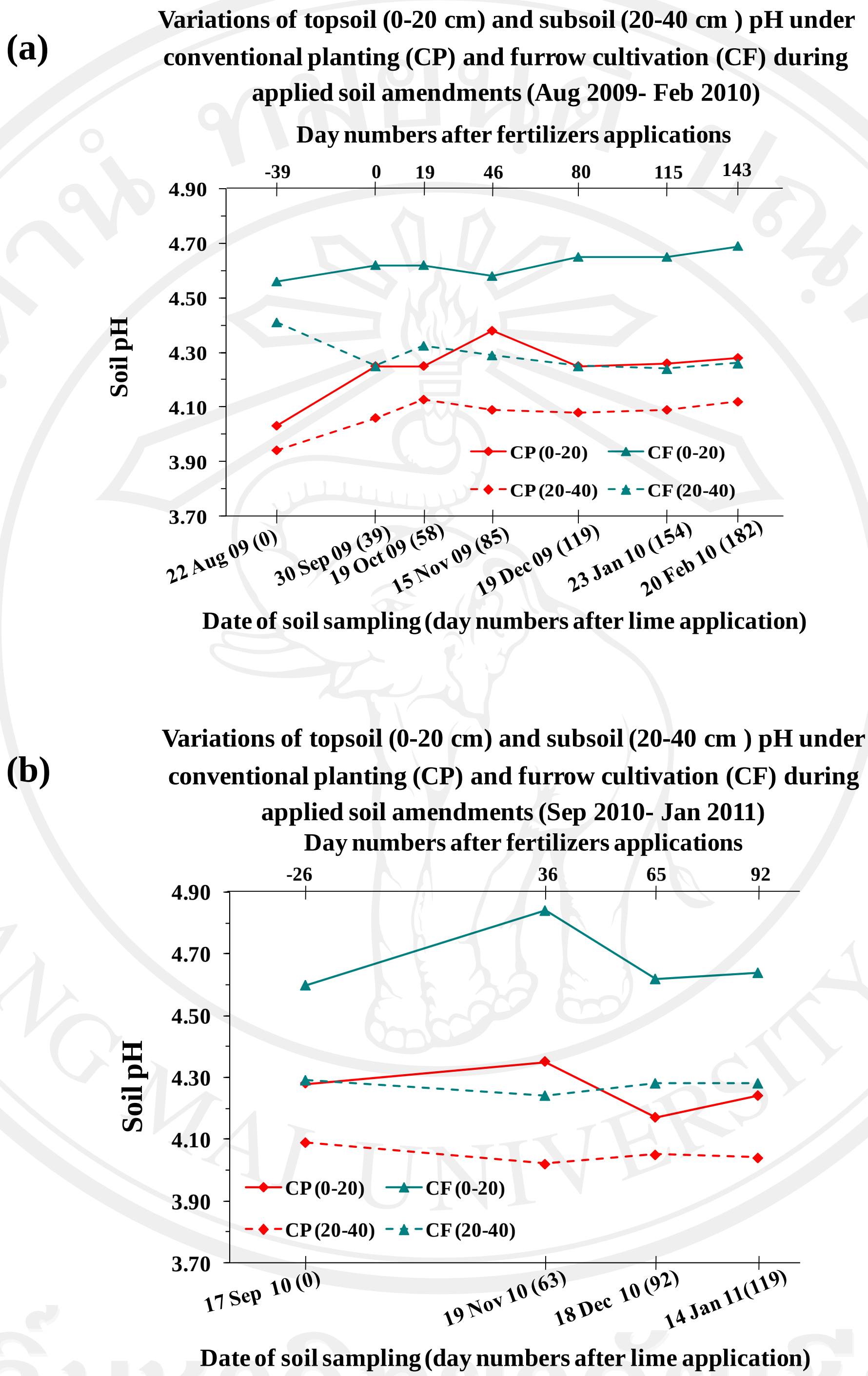
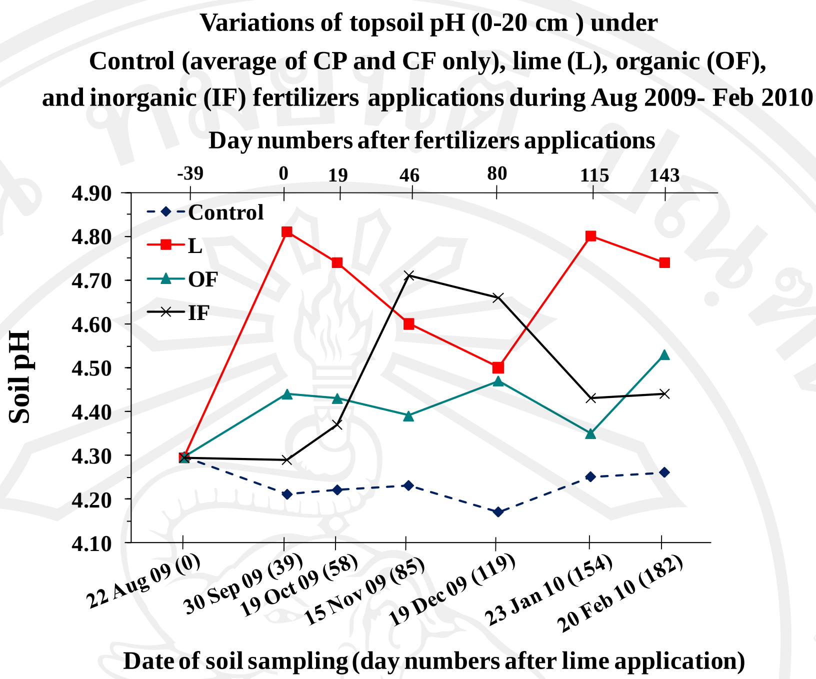


Figure 4.2.1 *Variations of topsoil (0-20 cm) and subsoil pH under conventional planting (CP) and furrow cultivation (CF) during (a) August, 2009 – February, 2010 and (b) September, 2010 - January, 2011 (The number in bracket is day numbers after lime application).*

(a)



(b)

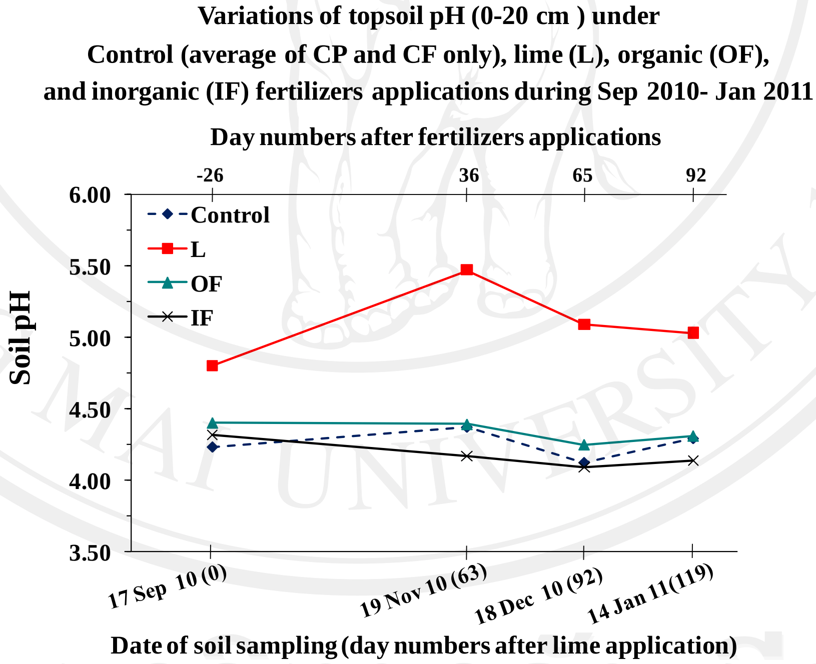


Figure 4.2.2 *Variations of topsoil pH (0-20 cm) under lime (L), organic fertilizer (OF) inorganic fertilizer (IF) applications and Control (average of CP and CF only) during (a) August, 2009- February, 2010 and (b) September, 2010- January, 2011 (The number in bracket is day numbers after lime application).*

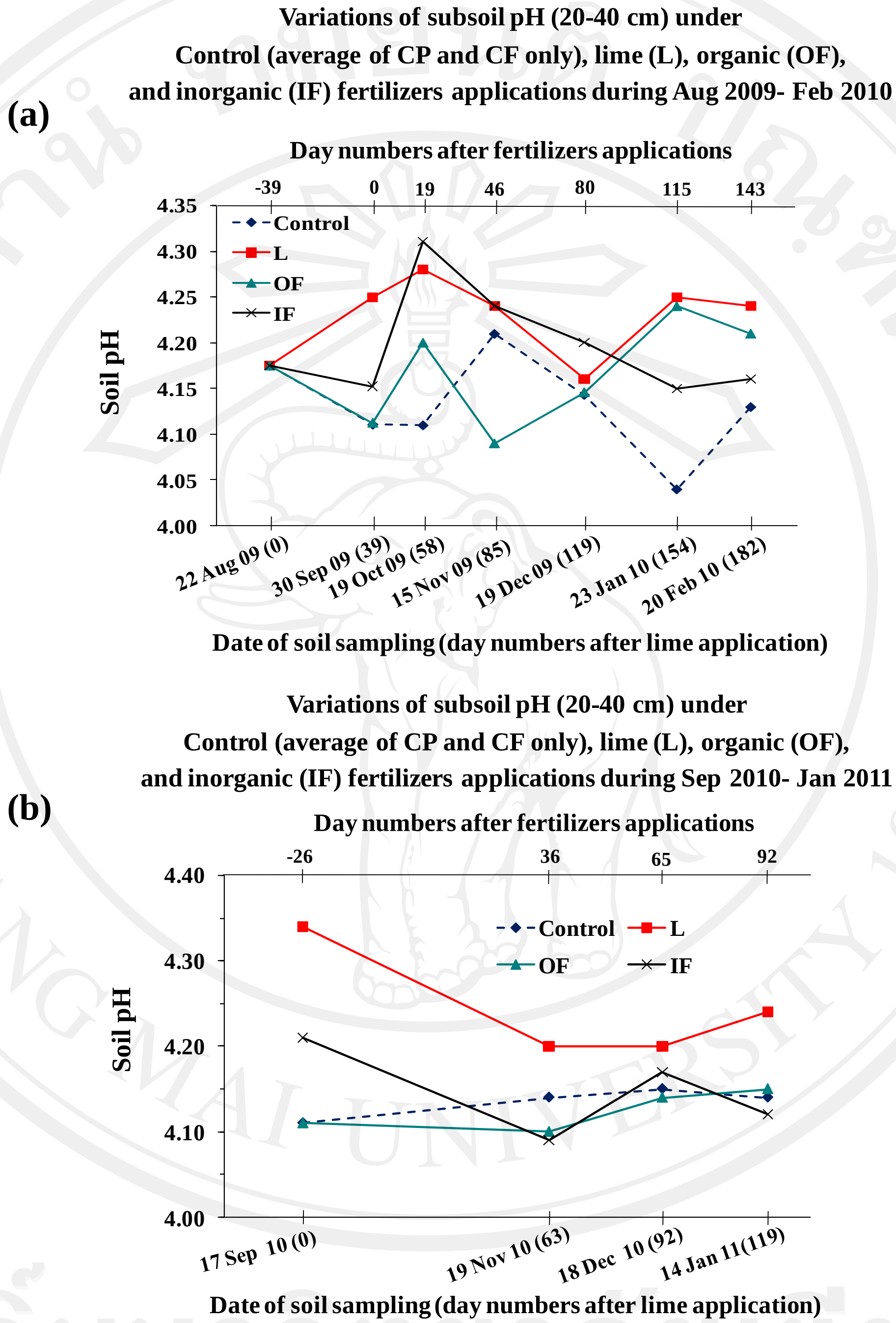


Figure 4.2.3 *Variations of subsoil pH (20-40 cm) under lime (L), organic fertilizer (OF) inorganic fertilizer (IF) applications and Control (average of CP and CF only) during (a) August, 2009- February, 2010 and (b) September, 2010- January, 2011 (The number in bracket is day numbers after lime application).*

4.2.2 Soil organic matter

The mean variations of organic matter (OM) contents in topsoil (0-20 cm) and subsoil (20-40 cm) as affected by different treatments are presented in Table 4.2.2a-b and Figures 4.2.4 – 4.2.6. Most soil OM contents in both topsoil and subsoil layers in CF plot were not different from those in CP plot (Table 4.2.2a-b). However, organic matter contents in subsoil layer under CP tended to be higher than those in CF plots throughout the 2 trial years (Table 4.2.2b), whilst the topsoil OM contents in CP and CF plots were not different (Table 4.2.2a). These might be caused by non-restricted or careless of furrow construction. The highest amount of OM contents also found in topsoil during the early dry season (November- December) under both CP and CF in both experimental years (Table 4.2.2a-b and Figure 4.2.4a-b). This might be caused by accumulation of plant and root residues from the previous crops. However, OM content in both topsoil and subsoil tended to be the lowest at the last stage of crop development (during January – February) under both cultivation practices which were 3.04 and 1.74 g/100g under CP and 2.93 and 1.42 g/100g under CF in the 1st year, whilst they were 3.12 and 1.59 g/100g under CP, and 3.12 and 1.34 under CF in the 2nd year respectively (Table 4.2.2a-b).

Table 4.2.2a-b and Figure 4.2.5 also show that OF and IF gave higher mean values of topsoil OM than either L or Control after liming and fertilizers applications in both studied years. These might be due to the higher nitrogen contents in organic and inorganic fertilizers giving better C:N ratio of the topsoil layer, enhancing microbial activity and decaying rate of organic material, consequently leading to the higher OM contents.

Table 4.2.2a *Mean variations of soil organic matter (OM) within 0-20 cm depth under different treatments, conventional planting (CP) and furrow cultivation (CF), Control (average of CP and CF only), lime (L), organic (OF) and inorganic (IF) fertilizers foliar, including zinc (Zn_1) and no zinc (Zn_0) applications, during August, 2009- January, 2011.*

Sampling date	Day numbers after			Cultivation Practices		LSD-1 (P<0.05)	Lime and fertilizers applications				LSD-2 (P<0.05)	Foliar-Zn spray		LSD-3 (P<0.05)
	liming	foliar-Zn, OF and IF applying	Lablab bean sowing	CP	CF		Control	L	OF	IF		Zn_1	Zn_0	
22-Aug-09	0	-39	-17	3.41	3.34	**ns**	3.34	3.34	3.34	3.34	**ns**	**na**	**na**	**na**
30-Sep-09	39	0	23	3.19	3.07	**ns**	2.63b	3.24a	3.32a	3.35a	**0.21**	**na**	**na**	**na**
19-Oct-09	58	19	42	3.27a	3.05b	**0.14**	2.83c	3.21b	3.32a	3.30a	**0.07**	**na**	**na**	**na**
15-Nov-09	85	46	69	3.39a	3.10b	**0.22**	3.03b	3.28a	3.33a	3.34 a	**0.18**	**na**	**na**	**na**
19-Dec-09	119	80	103	3.20	3.16	**ns**	2.77 b	3.27 a	3.25a	3.44 a	**0.26**	**na**	**na**	**na**
23-Jan-10	154	115	138	3.19	3.05	**ns**	2.95c	3.02bc	3.37a	3.12 b	**0.15**	**na**	**na**	**na**
20-Feb-10	182	143	166	3.04	2.93	**ns**	2.52c	3.11ab	2.9 b	3.34a	**0.35**	**na**	**na**	**na**
17-Sep-10	0	-26	-12	3.00	3.17	**ns**	2.75b	3.05ab	3.29a	3.25a	**0.43**	**na**	**na**	**na**
19-Nov-10	63	36	52	3.26	3.32	**ns**	3.04b	3.18ab	3.57a	3.38a	**0.41**	3.24	3.33	**ns**
18-Dec-10	92	65	81	3.41	3.34	**ns**	3.09c	3.19bc	3.58ab	3.64 a	**0.43**	3.35	3.39	**ns**
14-Jan-11	119	92	108	3.12	3.12	**ns**	3.05	3.08	3.34	3.03	**ns**	3.22	3.02	**ns**

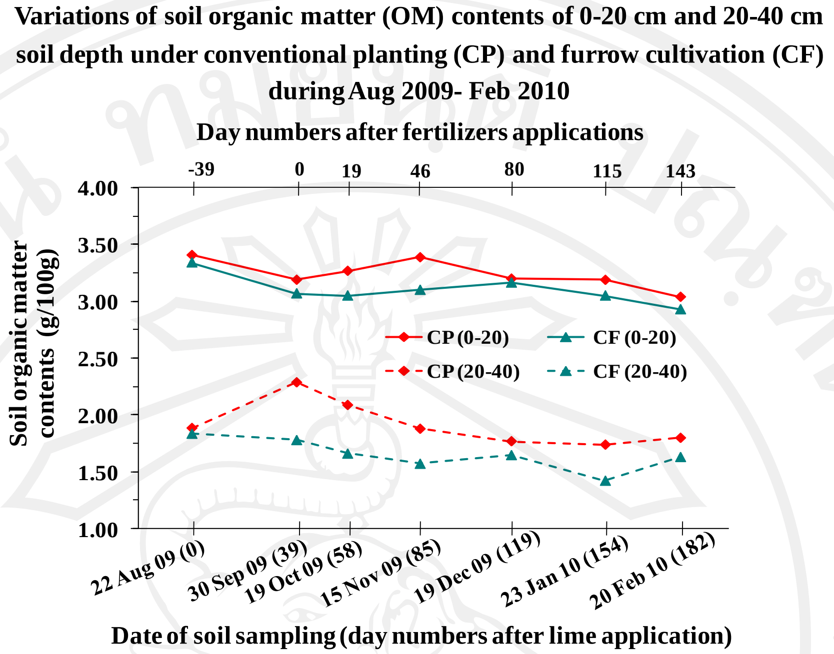
LSD-1, LSD-2 and LSD-3 are the least significant differences of the means, caused by different cultivation practices, lime, organic/inorganic fertilizers and foliar zinc applications respectively, for comparison at P < 0.05 a, b, and c represent differences between the means; ns : is none significant differences of the means. na: is not available

Table 4.2.2b *Mean variations of soil organic matter (OM) within 20-40 cm depth under different treatments, conventional planting (CP) and furrow cultivation (CF), Control (average of CP and CF only), lime (L), organic (OF) and inorganic (IF) fertilizers foliar, including zinc (Zn_1) and no zinc (Zn_0) applications, during August, 2009- January, 2011.*

Sampling date	**Day numbers after**			**Cultivation Practices**		**LSD-1 (P<0.05)**	**Lime and fertilizers applications**				**LSD-2 (P<0.05)**	**Foliar-Zn spray**		**LSD-3 (P<0.05)**
	liming	**foliar-Zn, OF and IF applying**	**Lablab bean sowing**	**CP**	**CF**		**Control**	**L**	**OF**	**IF**		**Zn_1**	**Zn_0**	
22-Aug-09	0	-39	-17	1.89	1.84	**ns**	1.86	1.86	1.86	1.86	**ns**	**na**	**na**	**na**
30-Sep-09	39	0	23	2.29a	1.78b	**0.28**	1.93b	2.00ab	2.17a	2.04	**0.19**	**na**	**na**	**na**
19-Oct-09	58	19	42	2.09a	1.66b	**0.37**	1.71c	1.92ab	2.08a	1.80b	**0.15**	**na**	**na**	**na**
15-Nov-09	85	46	69	1.88a	1.57b	**0.17**	1.65ab	1.81ab	1.86a	1.56b	**0.28**	**na**	**na**	**na**
19-Dec-09	119	80	103	1.77	1.65	**ns**	1.69	1.71	1.83	1.60	**ns**	**na**	**na**	**na**
23-Jan-10	154	115	138	1.74	1.42	**ns**	1.63	1.67	1.60	1.43	**ns**	**na**	**na**	**na**
20-Feb-10	182	143	166	1.80	1.63	**ns**	1.27b	1.99a	1.85a	1.76a	**0.42**	**na**	**na**	**na**
17-Sep-10	0	-26	-12	1.97	1.84	**ns**	1.63	2.00	2.08	1.93	**ns**	**na**	**na**	**na**
19-Nov-10	63	36	52	1.67	1.53	**ns**	1.43	1.67	1.69	1.63	**ns**	1.64	1.56	**ns**
18-Dec-10	92	65	81	1.61	1.37	**ns**	1.27	1.59	1.49	1.62	**ns**	1.51	1.48	**ns**
14-Jan-11	119	92	108	1.59	1.34	**ns**	1.40	1.39	1.68	1.39	**ns**	1.55	1.38	**ns**

LSD-1, LSD-2 and LSD-3 are the least significant differences of the means, caused by different cultivation practices, lime, organic/inorganic fertilizers and foliar zinc applications respectively, for comparison at $P < 0.05$ a, b, and c represent differences between the means; ns : is none significant differences of the means. na: is not available

(a)



(b)

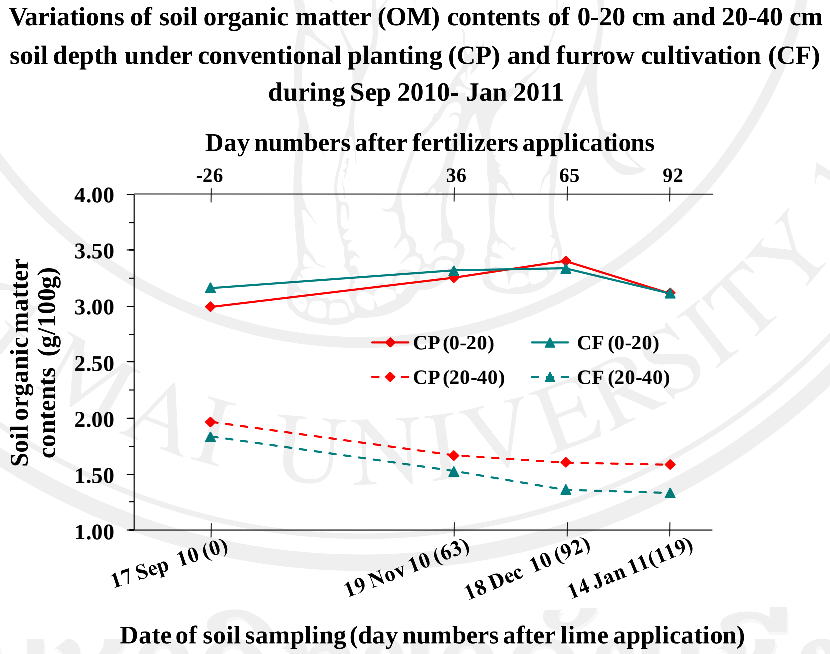
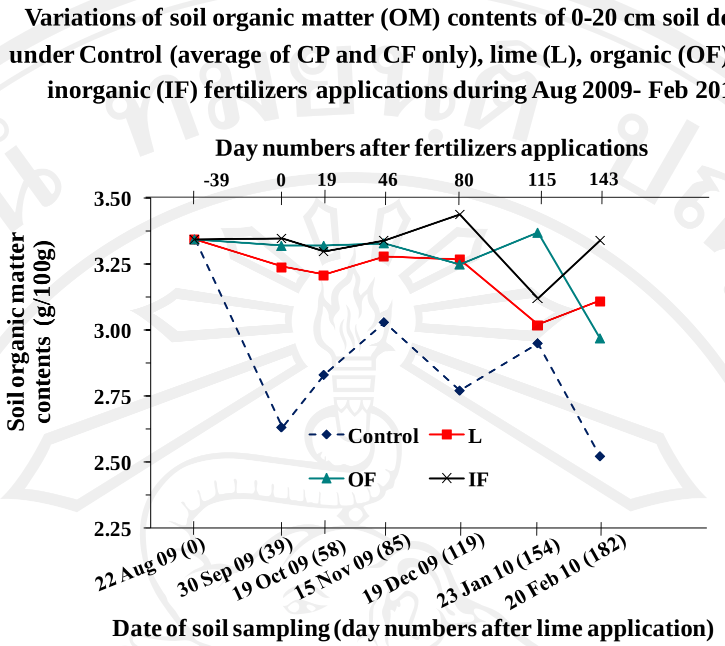


Figure 4.2.4 *Variations of topsoil (0-20 cm) and subsoil organic matter (OM) contents under conventional planting (CP) and furrow cultivation (CF) during (a) August, 2009 - February 2010 and (b) September, 2010 - January, 2011 (The number in bracket is day numbers after lime application).*

(a)



(b)

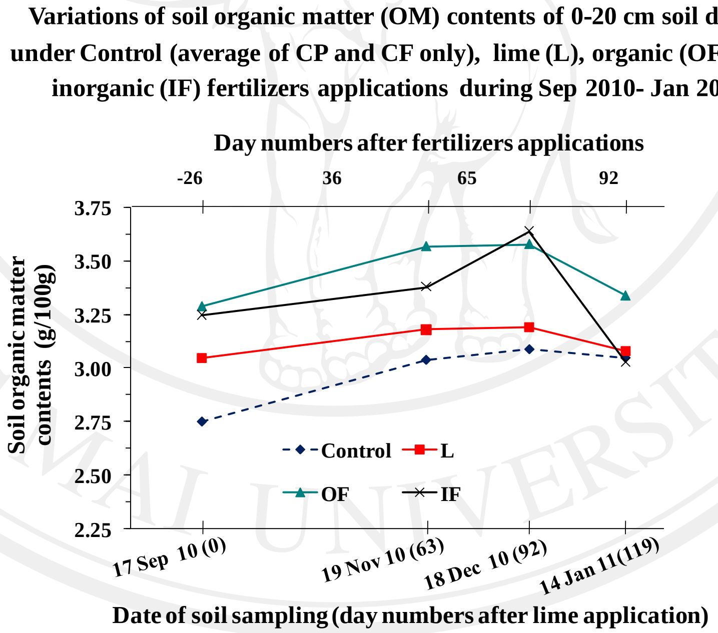
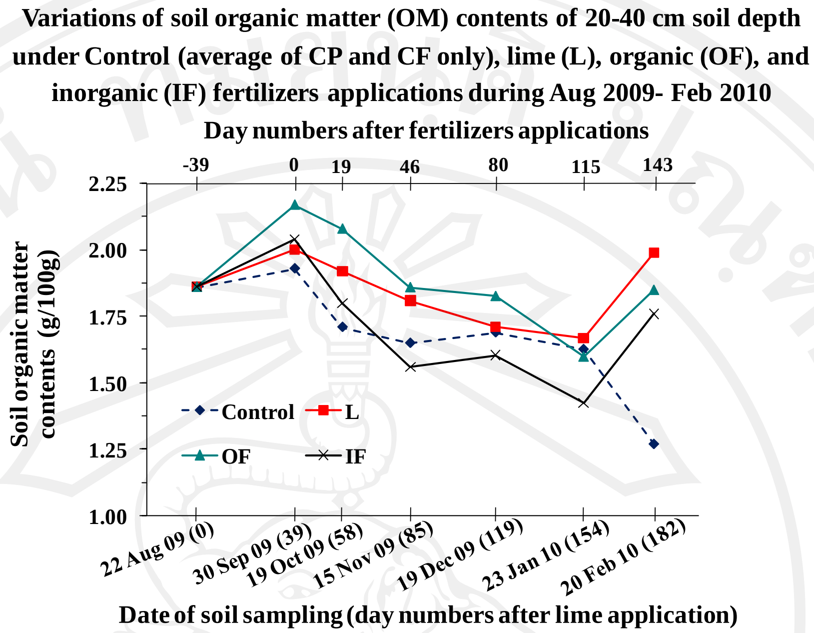


Figure 4.2.5 *Variations of topsoil (0-20 cm) organic matter (OM) contents under Control (average of CP and CF only), lime (L), organic (OF) and inorganic (IF) fertilizer applications during (a) August, 2009 – February, 2010 and (b) September, 2010 - January, 2011 (The number in bracket is day numbers after lime application).*

(a)



(b)

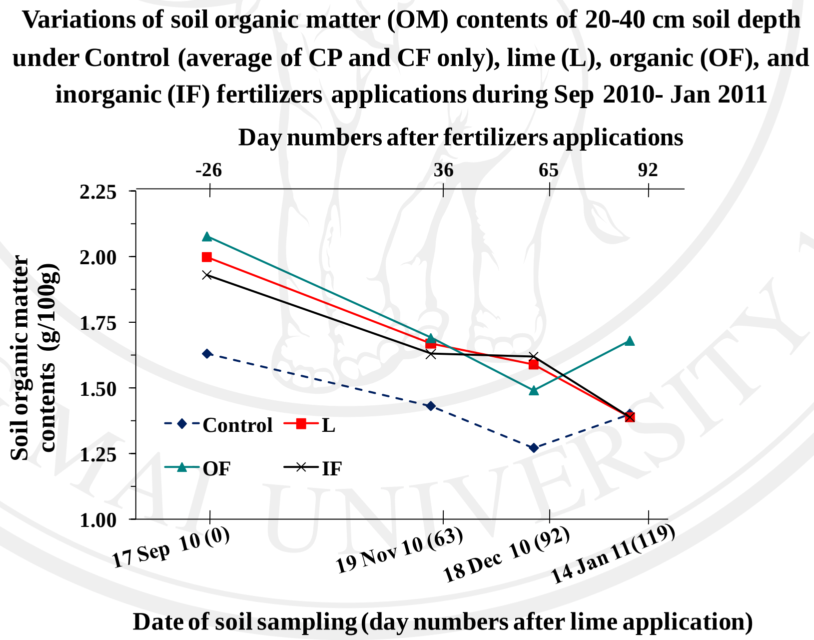


Figure 4.2.6 *Variations of subsoil (20-40 cm) organic matter (OM) contents under Control (average of CP and CF only), lime (L), organic (OF) and inorganic (IF) fertilizer applications during (a) August, 2009 – February, 2010 and (b) September, 2010 - January, 2011. (The number in bracket is day numbers after lime application).*

Similar to the results obtained as soil pH, foliar zinc spray (Zn_1) and no- zinc spraying (Zn_0) did not give significantly different soil OM contents in both topsoil and subsoil layers throughout the experimental periods.

4.2.3 Extractable phosphorus (Ext. P)

The effects of cultural practices (CP and CF), lime and fertilizers applications (L and OF/IF) including foliar zinc spray (Zn_1), on the variations of extractable phosphorus (Ext.P) within 0-20 cm and 20-40 cm soil depth at different crop growing periods during the two experimental years are presented in Table 4.2.3a-b and Figures 4.2.7 - 4.2.9.

Table 4.2.3a-b and Figure 4.2.7 show that most of topsoil and subsoil Ext. P values under CP were higher than those values under CF due to poorer crop development with less phosphorus consumption under CP than under CF (results are shown in 4.3). Ext.P in both topsoil and subsoil layers under both cultivation practices tended to be increased during the 1st year experiment (Figure 4.2.7a), and tended to be decreased (except the topsoil Ext.P under CP) during the 2nd experimental year (Figure 4.2.7b). This increased Ext.P might be caused by the combination effects of using soil amendments and cultivation practices including the variations of rainfall which affected to the phosphorus content in soil. The lower amount of Ext.P under CF could cause by better P- consumption of lablab bean under CF than that under CP.

Table 4.2.3a *Mean variations of extractable phosphorus (Ext.P) within 0-20 cm depth under different treatments, conventional planting (CP) and furrow cultivation (CF), Control (average of CP and CF only), lime (L), organic (OF) and inorganic (IF) fertilizers applications, including foliar zinc (Zn_1) and no zinc (Zn_0) applications, during August, 2009- January, 2011.*

Sampling date	**Day numbers after**			**Cultivation Practices**		**LSD-1 (P<0.05)**	**Lime and fertilizers applications**				**LSD-2 (P<0.05)**	**Foliar-Zn spray**		**LSD-3 (P<0.05)**
	liming	**foliar-Zn, OF and IF applying**	**Lablab bean sowing**	**CP**	**CF**		**Control**	**L**	**OF**	**IF**		**Zn_1**	**Zn_0**	
22-Aug-09	0	-39	-17	217a	150b	**29**	184	184	184	184	**ns**	**na**	**na**	**na**
30-Sep-09	39	0	23	198a	152b	**35**	155b	151b	207a	188ab	**45**	**na**	**na**	**na**
19-Oct-09	58	19	42	221a	155b	**51**	188ab	172b	214a	177b	**36**	**na**	**na**	**na**
15-Nov-09	85	46	69	271a	170b	**83**	211	242	203	226	**ns**	**na**	**na**	**na**
19-Dec-09	119	80	103	218	191	**ns**	179	212	210	218	**ns**	**na**	**na**	**na**
23-Jan-10	154	115	138	263a	200b	**44**	223b	216b	260a	228ab	**36**	**na**	**na**	**na**
20-Feb-10	182	143	166	259a	201b	**51**	225ab	216b	261a	218ab	**45**	**na**	**na**	**na**
17-Sep-10	0	-26	-12	227	242	**ns**	209b	202b	277a	252a	**42**	**na**	**na**	**na**
19-Nov-10	63	36	52	253a	204b	**30**	206	224	250	235	**ns**	212	246	**ns**
18-Dec-10	92	65	81	256	233	**ns**	209c	233b	274a	262a	**18**	231b	258a	**12**
14-Jan-11	119	92	108	265a	206b	**43**	210b	236ab	258a	239a	**28**	226	245	**ns**

LSD-1, LSD-2 and LSD-3 are the least significant differences of the means, caused by different cultivation practices, lime, organic/inorganic fertilizers and foliar zinc applications respectively, for comparison at $P < 0.05$ a, b, and c represent differences between the means; ns : is none significant differences of the means. na: is not available

***Table 4.2.3b** Mean variations of extractable phosphorus (Ext.P) within 20-40 cm depth under different treatments, conventional planting (CP) and furrow cultivation (CF), Control (average of CP and CF only), lime (L), organic (OF) and inorganic (IF) fertilizers applications, including foliar zinc (Zn_1) and no zinc (Zn_0) applications, during August, 2009- January, 2011.*

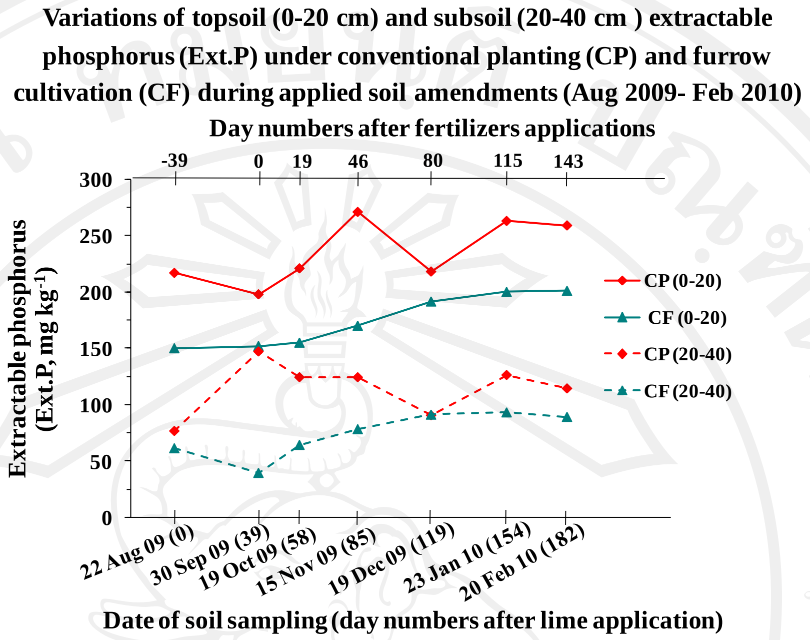
Sampling date	Day numbers after			Cultivation Practices		LSD-1 (P<0.05)	Lime and fertilizers applications				LSD-2 (P<0.05)	Foliar-Zn spray		LSD-3 (P<0.05)
	liming	foliar-Zn, OF and IF applying	Lablab bean sowing	CP	CF		Control	L	OF	IF		Zn_1	Zn_0	
22-Aug-09	0	-39	-17	76a	61b	**14**	69	69	69	69	**ns**	**na**	**na**	**na**
30-Sep-09	39	0	23	147a	39b	**21**	101a	91ab	113a	68b	**31**	**na**	**na**	**na**
19-Oct-09	58	19	42	124a	64b	**63**	96	94	100	79	**ns**	**na**	**na**	**na**
15-Nov-09	85	46	69	124a	78b	**35**	135a	104a	103ab	63b	**45**	**na**	**na**	**na**
19-Dec-09	119	80	103	90	91	**ns**	83	109	97	74	**ns**	**na**	**na**	**na**
23-Jan-10	154	115	138	126	93	**ns**	126a	115a	114a	83b	**32**	**na**	**na**	**na**
20-Feb-10	182	143	166	114	89	**ns**	103ab	109ab	114a	79b	**29**	**na**	**na**	**na**
17-Sep-10	0	-26	-12	124	87	**ns**	105	108	108	101	**ns**	**na**	**na**	**na**
19-Nov-10	63	36	52	95	76	**ns**	37b	67a	64a	55ab	**18**	48b	63a	**6**
18-Dec-10	92	65	81	81a	53b	**26**	37b	81a	68ab	82a	**36**	63	71	**ns**
14-Jan-11	119	92	108	77a	43b	**33**	40b	69a	71a	61a	**18**	54	67	**ns**

LSD-1, LSD-2 and LSD-3 are the least significant differences of the means, caused by different cultivation practices, lime, organic/inorganic fertilizers and zinc applications respectively, for comparison at $P < 0.05$ a, b, and c represent differences between the means; ns : is none significant differences of the means. na: is not available

The effects of lime (L), organic fertilizer (OF) and inorganic fertilizer (IF) applications presented in Table 4.2.3a-b and Figures 4.2.8 - 4.2.9 showed that the Ext.P in both topsoil and subsoil layers under all soil amendments applications were increased with highly fluctuated during the 1st year trial, from August, 2009 to February, 2010 (Figures 4.2.8a and 4.2.9a). These amounts of Ext.P tended to be unchanged during the 2nd year trial, from October, 2009 to January, 2011 (Figures 4.2.8b and 4.2.9b). OF application tended to give the highest amount of topsoil Ext.P compared to IF, L, and Control which gave the 2nd, the 3rd and the 4th high amount of Ext.P (Figures 4.2.8a-b). Inorganic fertilizer application (IF) gave the lowest amount of Ext.P in subsoil throughout the 1st year-trial when compared to the other treatments (Figures 4.2.9a). This lowest Ext.P values corresponded to the lowest OM contents under IF in subsoil during the 1st year (Figures 4.2.6a). Generally, plant rapidly use phosphate ion ($H_2PO_4^-$ and HPO_4^{2-}) or readily available phosphorus from inorganic fertilizer (IF) more than the mineralized organic phosphate from organic fertilizer (OF). Hence, the higher amounts of Ext.P remained in soil under OF than those under IF almost throughout the experimental period.

The above results indicated that the accumulation of available P in subsoil due to leaching of Ext.P caused by rainfall, during the 1st year was higher than the 2nd year (Figure 4.2.9a-b). However, the amount of Ext.P in subsoil was always lower than the topsoil throughout the studied periods under all soil amendment applications. This was corresponded to the general phenomena in all types of cultivated soil.

(a)



(b)

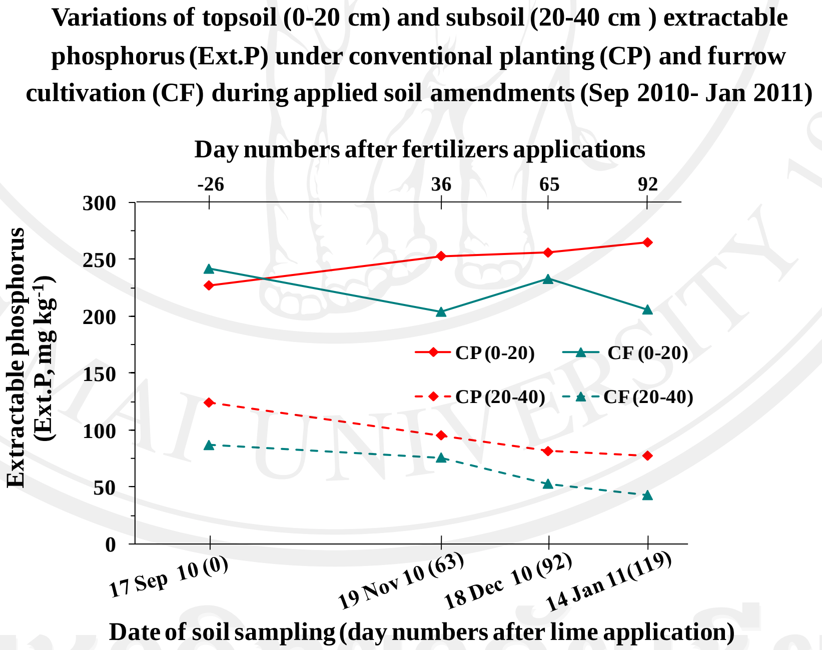
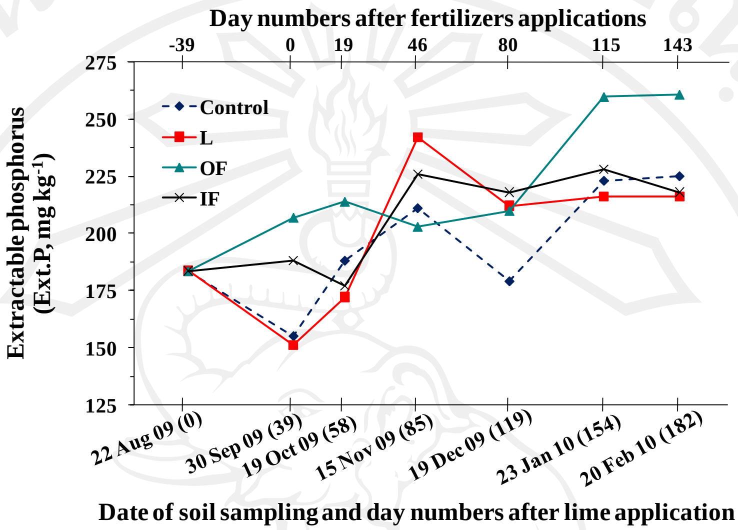


Figure 4.2.7 *Variations of topsoil (0-20 cm) and subsoil extractable phosphorus (Ext.P) under conventional planting (CP) and furrow cultivation (CF) during (a) August, 2009 – February, 2010 and (b) September, 2010 - January, 2011 (The number in bracket is day numbers after lime application).*

(a)

Variations of extractable phosphorus (Ext.P) of 0-20 cm soil depth under Control (average of CP and CF only), lime (L), organic (OF), and inorganic (IF) fertilizers applications during Aug 2009- Feb 2010



(b)

Variations of extractable phosphorus (Ext.P) of 0-20 cm soil depth under Control (average of CP and CF only), lime (L), organic (OF), and inorganic (IF) fertilizers applications during Sep 2010- Jan 2011

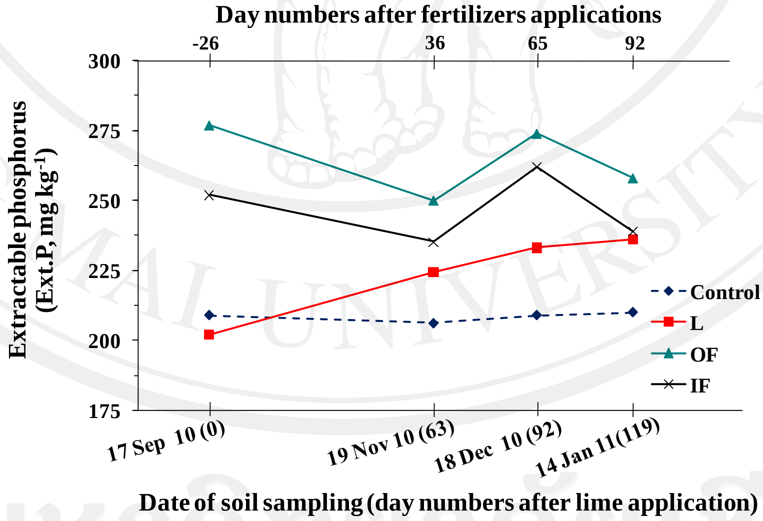


Figure 4.2.8 *Variations of topsoil (0-20 cm) extractable phosphorus (Ext.P) under Control (average of CP and CF only), lime (L), organic (OF) and inorganic (IF) fertilizer applications during (a) August, 2009 – February, 2010 and (b) September, 2010 - January, 2011 (The number in bracket is day numbers after lime application).*

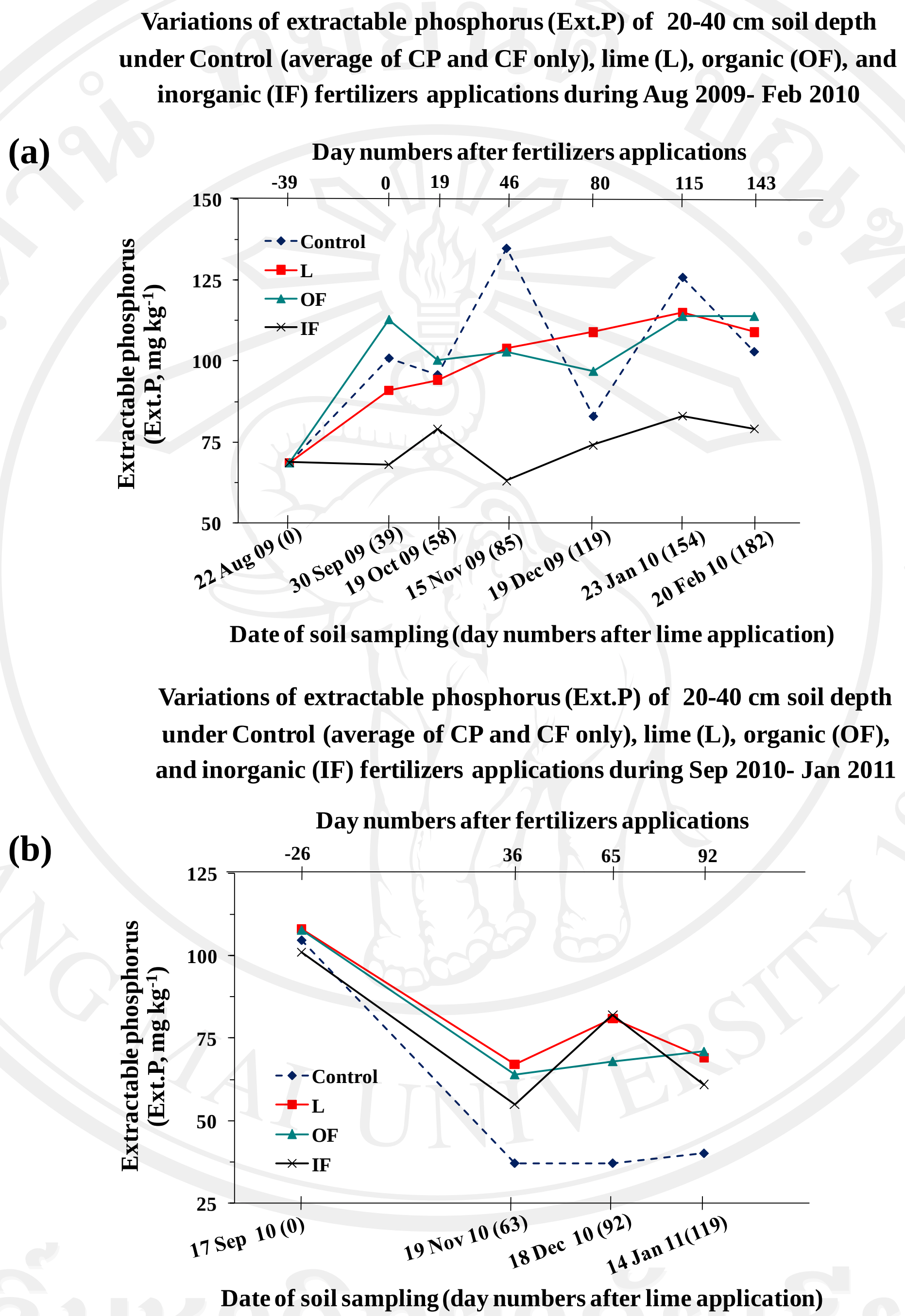


Figure 4.2.9 *Variations of subsoil (20-40 cm) extractable phosphorus (Ext.P) under Control (average of CP and CF only), lime (L), organic (OF) and inorganic (IF) fertilizer applications during (a) August, 2009 – February, 2010 and (b) September, 2010 - January, 2011 (The number in bracket is day numbers after lime application).*

The amounts of Ext.P in both topsoil and subsoil under foliar Zn (Zn_1) and no Zn (Zn_0) applications were not significantly different (Table 4.2.3a-b). However, Zn_1 tended to give lower amount of Ext.P than Zn_0 during soil measurement periods in the 2^{nd} year trial (November, 2010 – January, 2011). This was caused by the higher P-consumption due to the better development of lablab bean growing under Zn_1 than those under Zn_0.

The largely variations of the Ext.P amount under each treatment during the 2 studied years were affected by the interactive effects among the cultivation practices, liming, fertilizer applications, crop developments and rainfall distributions during the studied periods. (Panomtoranichagul et al., 2009; Tisdale and Werner, 1966; Thomas, 1970).

4.2.4 Extractable zinc (Ext.Zn)

Table 4.2.4 shows the effect of cultivation practices (CP and CF plot), soil amendments (L, OF, IF) applications and foliar zinc (Zn_1 and Zn_0) on variations of Ext.Zn in soil. The results showed that Ext.Zn under CP was lower than under CF. These were caused by (i) Zn within topsoil was lost trough surface runoff and soil erosion which were higher in CP plot than those in CF plot (Panomtaranichagul and Narubarn, 2008). (ii) The antagonistic effects between P and Zn, the available Zn were reduced under high P condition (Zhu et al., 2001). In addition, it was found that liming tended to decrease the amount of Ext.Zn from 1.29 to 0.99 mg kg^{-1} during August, 2009-January, 2011. While Control and both fertilizer applications (OF/IF) tended to increase the amount of Ext.Zn. Liming also gave the lowest Ext.Zn, compared to Control, inorganic and organic fertilizer application which gave the highest, 2nd and 3rd high amount of Ext.Zn respectively. The lowest Ext.Zn under liming might be due to the increased soil pH, causing the increased formation of zinc-hydroxide, leading to reduction of the soluble Zn in soil.

The amounts of Ext.Zn in topsoil (0-20 cm) under foliar Zn (Zn_1) and no Zn (Zn_0) applications were not significantly different. However, foliar Zn spray (Zn_1) tended to give the lower Ext.Zn amount than no Zn spray (Zn_0).

Table 4.2.4 *Mean variations of Extractable zinc (Ext.Zn) within 0-20 cm soil depth under conventional planting (CP) and furrow cultivation (CF), Control (average of CP and CF only), lime (L), organic fertilizer (OF), inorganic fertilizer (IF) applications, including foliar zinc (Zn_1) and no zinc (Zn_0) spray during 2 years experiment (August, 2009- January, 2011).*

Extractable Zinc (Ext. Zn, mg kg^{-1})	**Sampling date**	**Cultivation Practices**		**LSD-1 P<0.05**	**Lime and fertilizers applications**				**LSD-2 P<0.05**	**Foliar-Zn spray**		**LSD-3 P<0.05**
		CP	**CF**		**Control**	**L**	**OF**	**IF**		**Zn_1**	**Zn_0**	
within 0-20 cm soil depth	**22-Aug-09**	**0.46 b**	**2.19 a**	**1.19**	**1.29**	**1.29**	**1.29**	**1.29**	**ns**	**1.29**	**1.29**	**ns**
	17-Sep-10	**0.80 b**	**1.95 a**	**0.70**	**2.47 a**	**0.78 b**	**1.25 b**	**1.04 b**	**1.06**	**1.29**	**1.46**	**ns**
	19-Nov-10	**0.82 b**	**2.39 a**	**1.07**	**2.74 a**	**0.76 b**	**1.49 b**	**1.53 b**	**1.11**	**1.49**	**1.7**	**ns**
	14-Jan-11	**0.71 b**	**3.31 a**	**2.02**	**3.39 a**	**0.99 c**	**1.31 c**	**2.33 b**	**1.00**	**1.93**	**2.08**	**ns**

LSD-1, LSD-2 and LSD-3 are the least significant differences of the means, caused by different cultivation practices, applications of lime, organic/inorganic fertilizers and zinc applications respectively, for comparison at $P < 0.05$

a, b, and c represent differences between the means; ns : is none significant differences of the means. na: is not available

4.3 Vegetative growth (height), total phosphorus and zinc contents in tissue, total dry matter and seed yield of lablab bean

Crop growth and yield data were collected during lablab bean growing and yield harvesting as total dry matter above ground level and field dry seed yield of lablab bean. Total phosphorus and zinc contents in plant tissue were analyzed at the last stage of lablab ban development. The results are presented in Tables 4.3.1 - 4.3.3 and Figures 4.3.1 -4.3.7.

4.3.1 Lablab bean development (Height of lablab bean)

The vegetative growth of lablab bean was measured by plant height which had been measured continuously every month. The lablab bean height was affected by (i) cultivation practices, (ii) soil amendments applications, and (iii) foliar zinc application which are presented in Table 4.3.1 and Figures 4.3.1-4.3.5.

(i) Effects of cultivation practices on lablab bean height

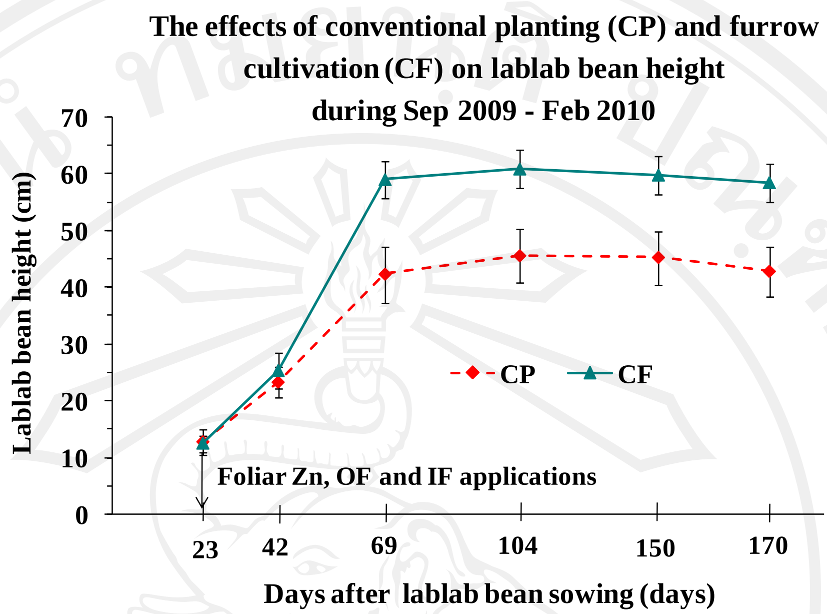
Table 4.3.1 and Figures 4.3.1-4.3.2 show that lablab bean growth rates under furrow cultivation (CF) were higher than those under conventional planting (CP) significantly throughout the 2 studied years (during September, 2009 – February, 2010, and September, 2010 – January, 2011). The highest growth of lablab bean in CF and CP plot during the 1st year experiment were 60.91 and 45.54 cm height after sowing 104 days, and were 49 and 36 cm height after sowing 108 days during the 2nd year experiment respectively (Table 4.3.1 and Figure 4.3.1-4.3.3). These results were supported by the higher water harvested in CF plot than CP plot, leading to better crop growth and yields in CF plot than in CP plot, during the late rainy - dry season (Panomtoranichagul et al., 2009).

Table 4.3.1 *Mean variations height (cm) of lablab bean during 2 period crop planting (September, 2009- February, 2010 and September, 2010-January, 2011) under conventional planting (CP) and furrow cultivation (CF), Control (average of CP and CF only), lime (L), organic fertilizer (OF), and inorganic fertilizer (IF) applications, including foliar zinc (Zn_1) and no zinc (Zn_0) spray.*

Sampling date	**Day numbers after lablab bean sowing**	**Cultural Practices**		**LSD-1 (P<0.05)**	**Lime and fertilizers applications**				**LSD-2 (P<0.05)**	**Foliar-Zn spray**		**LSD-3 (P<0.05)**
		CP	**CF**		**Control**	**L**	**OF**	**IF**		**Zn_1**	**Zn_0**	
		1st year of lablab bean growing										
30-Sep-09	23	12.75	12.41	**ns**	11.83	13.25	12.66	12.58	**ns**	12.75	12.41	**ns**
19-Oct-09	42	23.25b	25.25a	**1.72**	23.50b	26.25ab	27.16a	26.08ab	**2.94**	27	24.5	**ns**
15-Nov-09	69	42.29b	59.04a	**4.07**	43.25c	43.25c	55.58b	60.58a	**3.77**	52.12	49.20	**ns**
19-Dec-09	104	45.54b	60.91a	**5.89**	45.66c	45.83c	57.50b	61.92a	**3.85**	54.67a	50.79b	**3.52**
23-Jan-10	150	45.24b	59.84a	**4.52**	46.62c	45.56c	57.22b	61.01a	**3.27**	54.67a	50.00b	**3.52**
20-Feb-10	170	42.79b	58.50a	**6.16**	43.91c	44.50c	55.08b	59.03a	**3.62**	52.71a	48.58b	**3.04**
		2nd year of lablab bean growing										
15-Oct-10	17	9.66	12.03	**ns**	9.75c	10.08bc	11.41ab	12.25a	**1.43**	11.37	10.32	**ns**
19-Nov-10	52	25.88b	32.42a	**2.71**	24.83b	26.52b	32.56a	32.75a	**2.61**	30.67	27.63	**ns**
18-Dec-10	81	30.52b	40.67a	**5.58**	30.91b	30.92b	37.33a	38.65a	**6.18**	34.20	31.00	**ns**
14-Jan-11	108	36.97b	48.86a	**8.28**	31.28b	36.97b	47.53a	49.91a	**9.12**	43.02a	32.83b	**6.32**

LSD-1, LSD-2 and LSD-3 are the least significant differences of the means, caused by different cultivation practices, lime, organic and inorganic fertilizers applications including zinc spray, for comparison at $P < 0.05$ a, b, and c represent differences between the means; ns : is none significant differences of the means. na: is not available

(a)



(b)

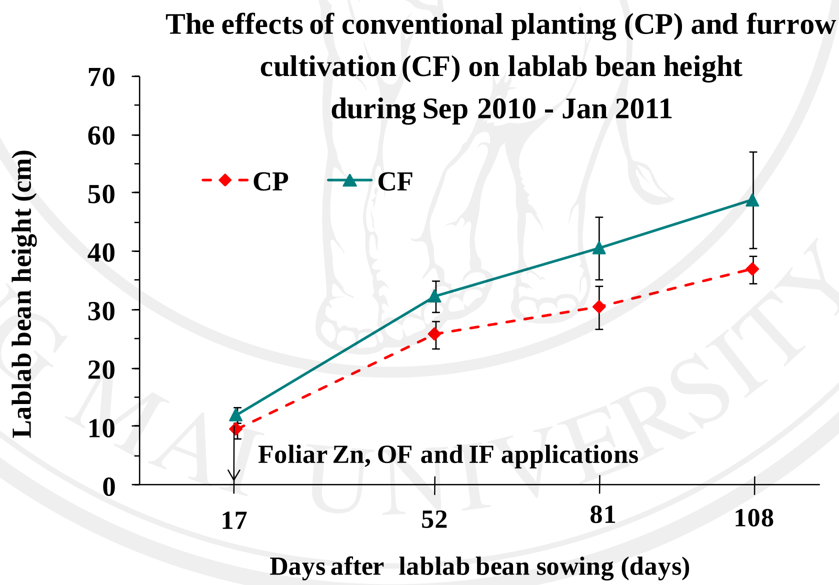


Figure 4.3.1 *Lablab bean growths (height) under conventional planting (CP) and furrow cultivation (CF) (a) in the 1st year of experiment, September, 2009-February, 2010 and (b) in the 2nd year of experiment, September, 2010- January, 2011.*

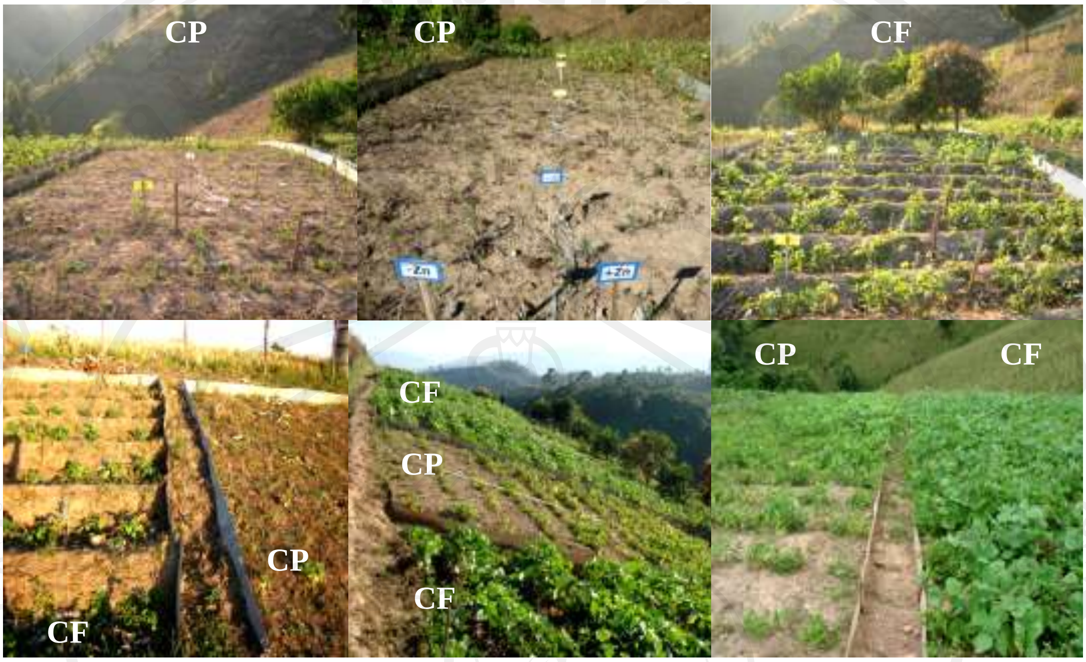


Figure 4.3.2 *Lablab bean growths under conventional planting (CP) and furrow cultivation (CF)*

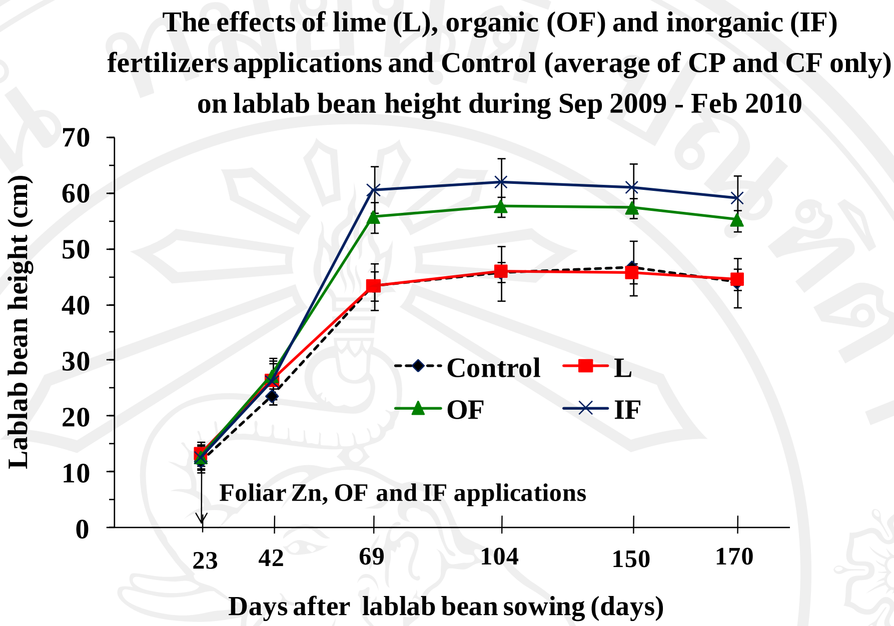
Water is the most crop growth limiting factor and is the key factor in nutrient uptake by root absorption, mass flow, and diffusion (Halvin et al., 1999). Therefore, water and fertilizer use efficiencies under higher water harvest treatment (CF) gave better crop growth and development than the lower water harvest soil treatment (CP) (Figures 4.3.1-4.3.2).

(ii) Effect of lime, organic and inorganic fertilizers applications on lablab bean development

Table 4.3.1 and Figure 4.3.3 show that height of the lablab bean significantly responded to fertilizers applications. Inorganic fertilizer (IF) and organic fertilizer (OF) application gave the highest and the 2nd high of lablab bean height compared to either liming (L) or Control (average of CP and CF only) which gave the 3rd and the lowest height of lablab bean respectively. The mean values of plant height under IF application was 61.92 cm, and under OF, L and Control were 57.5, 45.83 and 45.66 cm respectively on 19th December, 2009 which was 104 days after lablab bean sowing in the 1st year experiment (Figure 4.3.3a). The effects of soil amendments applications on crop growth during the 2nd year (Figure 4.3.3b) also showed the same trends as the 1st results. The highest and 2nd high crop heights were 49.91 and 47.53 cm found under IF and OF respectively, which were significantly higher than those under L and Control, 36.97 and 31.28 cm height respectively (Table 4.3.1 and Figure 4.3.3b). Liming did not give significantly different crop height from the Control (Figure 4.3.3) because, the amount of applied lime might not be sufficient for raising the soil pH to the optimum range for increasing the nutrient availability such as available phosphorus. Furthermore, the plant nutrient particularly phosphorus availability was slowly increased after liming due to slowly increased soil pH caused by lime application, leading to poorer crop development or lower plant height under liming (L) than under both fertilizer applications (OF/IF).

Table 4.3.1 and Figure 4.3.3 also show that the height of lablab bean at different growing stages in the 2nd year were lower than the 1st year experiment. These results were influenced by different amounts and distributions of rainfall between the 2 studied years. The total rainfall after lablab bean sowing was 325 mm in 2009 which was higher than 262 mm in 2010, hence, crop development in 2009 was better than those in 2010.

(a)



(b)

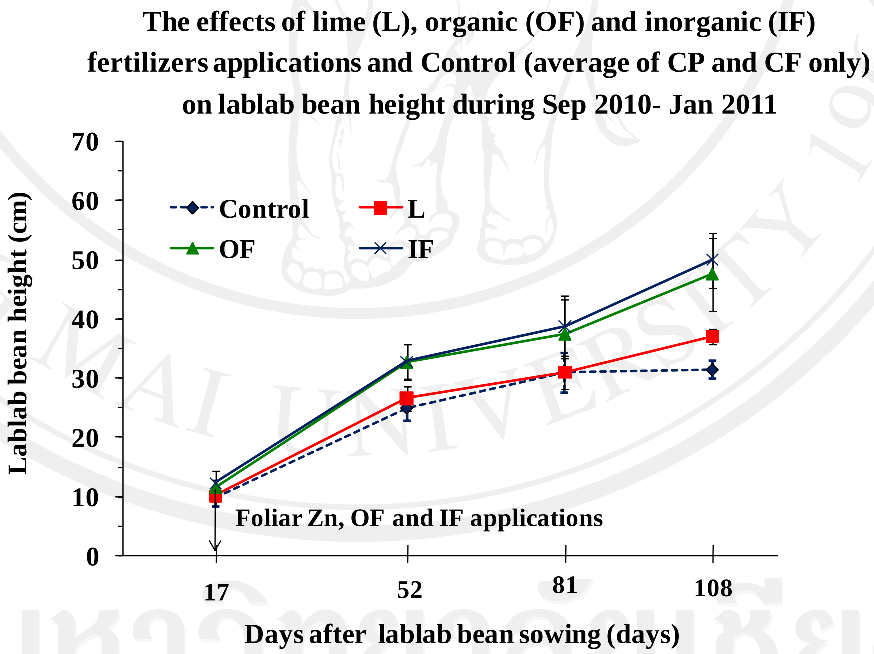


Figure 4.3.3 *Lablab bean growth after liming (L), organic fertilizer application (OF), inorganic fertilizer application (IF) and Control (average of CP and CF only) at the (a) September 2009- February 2010 and (b) September, 2010- January, 2011.*

(iii) Effect of foliar zinc spray on lablab bean growth

The height of lablab bean under Zn_1 and Zn_0 treatment were not significantly different (Table 4.3.1 and Figure 4.3.4). Generally, plant growth (height) would greater respond to foliar Zn application only under sufficient soil moister content in the irrigation area (Movahhedy-Dehnanavy et al., 2009 and Khan et al., 2003). However, foliar zinc spray (Zn_1) using zinc sulphate solution gave better vegetative growth and height of lablab bean than those without foliar zinc spray (Zn_0) during the dry season without any irrigation system or under rainfed condition during the 2 experimental years (2009 – 2011) (Figures 4.3.4- 4.3.5). Zinc is the essential element for several plant enzyme and plant hormone productions (i.e. Indole Acetic Acid, IAA), which function to encourage the vegetative growth rate of plant. In addition Zn increased plant vigor and tolerance to unsuitable conditions such as high temperature, plant disease and pest, etc. Therefore, foliar zinc spray on lablab bean tended to give higher crop growth and plant vigor than none Zn sprayed during the dry seasons in both experimental years (2009-2011).

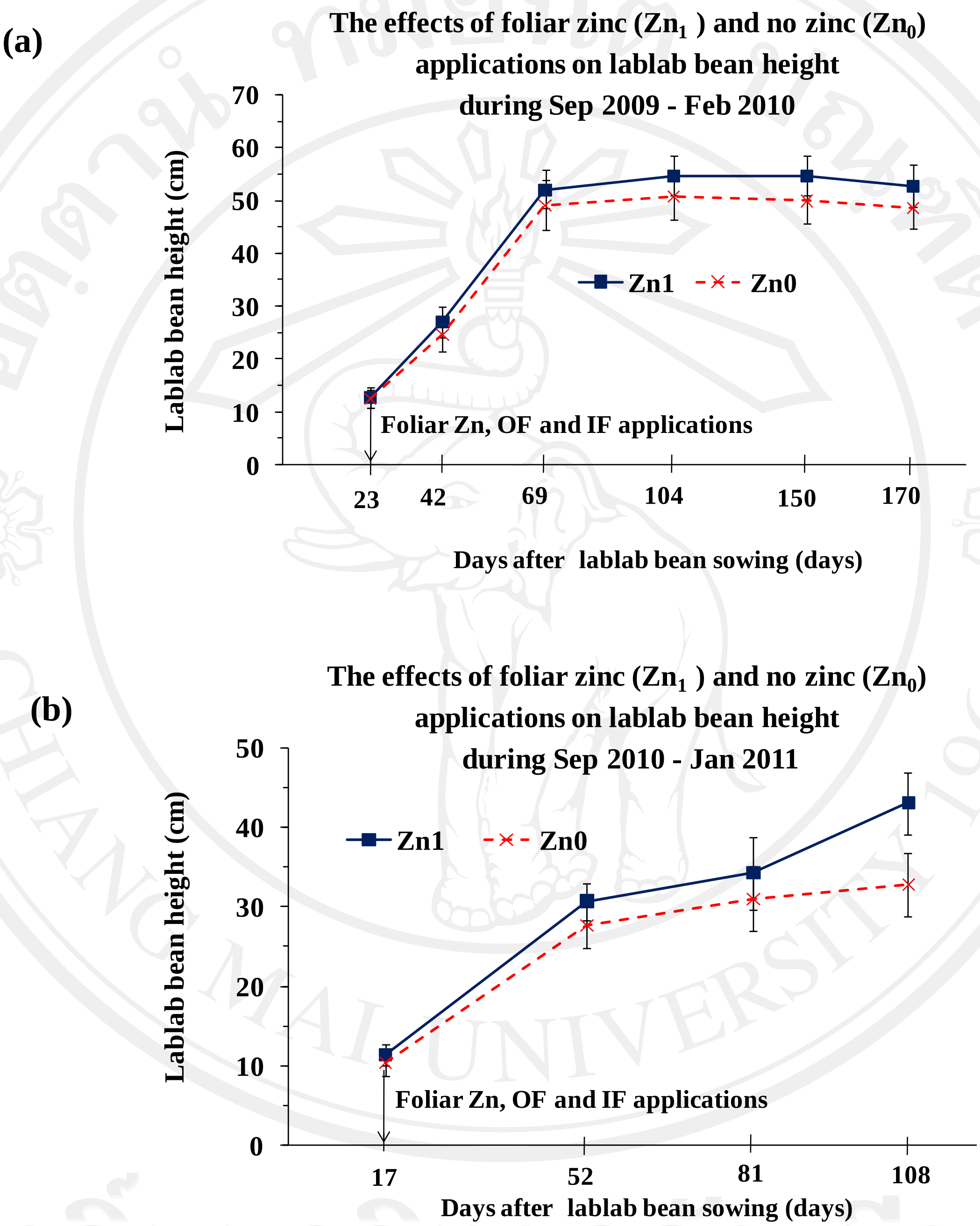


Figure 4.3.4 *Lablab bean growth under foliar zinc (Zn_1) and no zinc (Zn_0) applications (a) the 1st year- experiment (September, 2009- February, 2010) and (b) the 2nd year -experiment (September, 2010- January, 2011).*

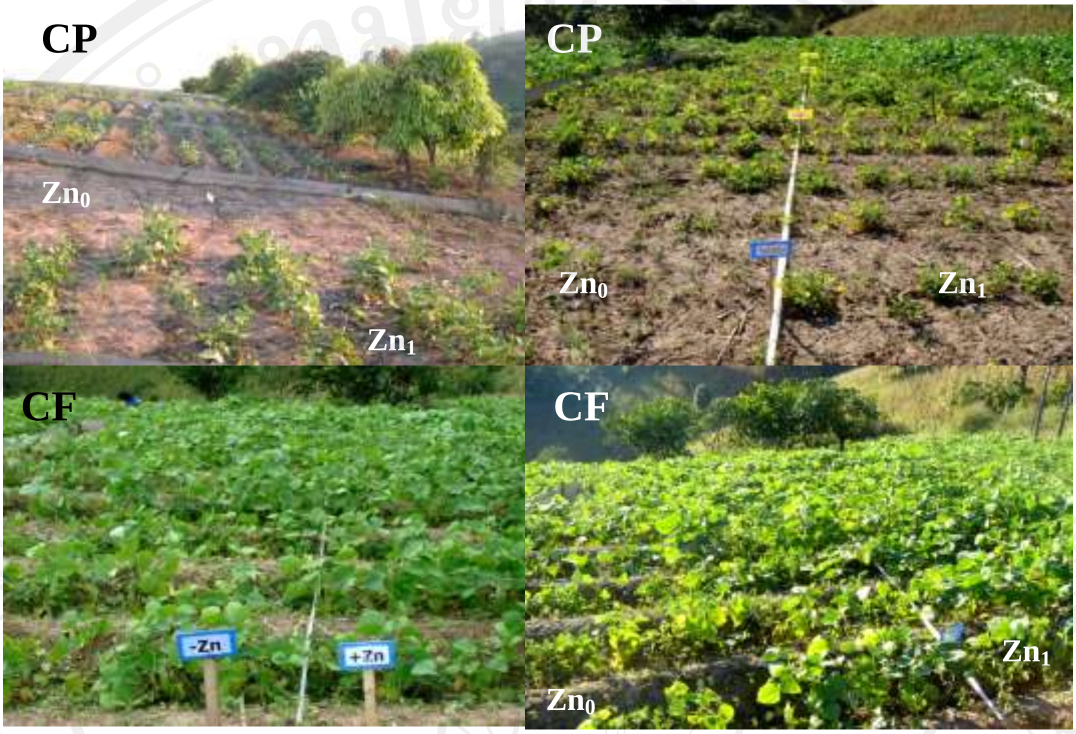


Figure 4.3.5 *Lablab bean growth under foliar zinc (Zn_1) and no-zinc (Zn_0) applications in conventional planting (CP) and furrow cultivation (CF) plot*

4.3.2 Phosphorus and zinc contents in plant tissue of lablab bean

The effects of cultivation practices (CP and CF), lime (L), fertilizers (OF/IF) and zinc (Zn) applications on total phosphorus (total P) and total zinc (total Zn) contents in plant tissues of lablab bean are shown as total P and Zn concentration in Table 4.3.2 and total P and Zn uptake per unit growing area in Table 4.3.3

(i) Total phosphorus concentration in plant tissue of lablab bean

Table 4.3.2 shows that furrow cultivation (CF) significantly gave the higher amount of total P contents (3,156 and 1,723 mg kg^{-1}) than those given by CP (2,905 and 1,241 mg kg^{-1}) in total plant biomass above ground level for the 1st and the 2nd experimental years respectively.

Table 4.3.2 *Total phosphorus (total P) and total zinc (total Zn) in plant tissue at the maturity stage under conventional planting (CP) and furrow cultivation (CF), Control (average of CP and CF only), lime (L), organic fertilizer (OF), inorganic fertilizer (IF), foliar zinc (Zn_1) and no zinc (Zn_0) applications in the 1^{st} and the 2^{nd} year experiment.*

	Sampling date	**Cultural Practices**		**LSD-1 P<0.05**	**Lime and fertilizers applications**				**LSD-2 P<0.05**	**Foliar-Zn spray**		**LSD-3 P<0.05**
		CP	**CF**		**Control**	**L**	**OF**	**IF**		**Zn_1**	**Zn_0**	
Total Phosphorus ($mg\ kg^{-1}$)	**20-Feb-10[1]**	2,905b	3,156a	**235**	3,204a	3,121a	2,701b	3,096a	**233**	3,280a	2,782b	**187**
	14-Jan-11[2]	1,241b	1,723a	**204**	1,145b	1,617a	1,561a	1,606a	**246**	1,640a	1,324b	**238**
Total Zinc ($mg\ kg^{-1}$)	**20-Feb-10[1]**	37b	51a	**8.99**	47	38	45	49	**ns**	49a	39b	**9.69**
	14-Jan-11[2]	25b	34a	**6.38**	35	27	26	31	**ns**	31	28	**ns**

[1] *20^{th} February, 2010 is the harvesting stage of the 1^{st} trial year*

[2] *14^{th} January, 2011 is the harvesting stage of the 2^{nd} trial year*

LSD-1, LSD-2 and LSD-3 are the least significant differences of the means caused by different cultivation practices , soil amendments (lime, organic/inorganic fertilizer) applications and foliar zinc application for comparison at P<0.05, a and b represent differences between the means; ns : is none significant differences of the means

Table 4.3.2 also shows that total P contents in plant under L, OF and IF applications were significantly different from each others. OF gave the lowest amount of total P in plant at 2,701 mg kg^{-1}, in the 1^{st} year compared to others soil amendments, Control, L and IF, L which gave total P content in plant at 3,204, 3,121, and 3,096 mg kg^{-1} respectively. However, the lowest total P content in plant was found under Control which was 1,145 mg kg^{-1}, compared to those found under L, IF and OF which were 1,617, 1,606 and 1,561 mg kg^{-1} respectively in the 2^{nd} experimental year. The amounts of total P contents in plant under all treatments in the 1^{st} year were higher than those in the 2^{nd} year almost 100%. These results corresponded to the results of plant growth, biomass and seed production of lablab bean obtained in 4.3.1 and 4.3.3 respectively. The different total P content between the 2 experimental years were caused by the different lablab bean development with different sowing time and growing stages under limited available water, due to different rainfall distributions between the 2 years, leading to the higher total P contents in lablab bean in the 1^{st} year than those in the 2^{nd} year.

The effect of foliar Zn spray also significantly gave higher total P content in plant higher than that given by Zn_0 in both studied years. The mean values of total P contents in plant under Zn_1 and Zn_0 were 3,280 and 2,782 mg kg^{-1} in the 1^{st} year and were 1,640 and 1,324 mg kg^{-1} in the 2^{nd} trial year.

(ii) Total zinc concentration in plant tissue of lablab bean

Table 4.3.2 shows that furrow cultivation (CF) gave the total Zn content in plant tissue of lablab bean which grown in the 1st and 2nd experimental year at 51 and 35 mg kg^{-1} respectively. These amounts of total Zn given by CF were significantly higher than those given by conventional planting (CP) at 37 and 26 mg kg^{-1} in the 1st and 2nd trial year respectively. These results corresponded to the amount of Ext.Zn in soil in the CF and CP plot as described in 4.2.4. However, total Zn contents in lablab bean tissue under all soil amendments applications (Control, L, OF and IF) were not significantly different from each others.

Table 4.3.2 also shows that foliar Zn application (Zn_1) tended to give total Zn content in plant higher than those under no zinc application (Zn_0) in both trial-years. The total Zn contents in plant with and without foliar Zn spray, Zn_1 and Zn_0 were 49 and 32 mg kg^{-1} in the 1st year, and were 39 and 28 mg kg^{-1} in the 2nd year respectively.

(iii) Total P and Zn uptake per unit growing area

The above mentioned total P and Zn in plant were the concentrations of P and Zn which did not represent the total P and Zn consumption of crop or actual soil available P and Zn uptake by plant. Therefore, the total amounts of P and Zn uptakes by the crop under different treatments were calculated as total P and Zn in total biomass production of lablab bean above ground level, which are presented in Table 4.3.3.

Table 4.3.3 *The amount of total phosphorus and total zinc uptake (total P-uptake and total Zn-uptake (kg ha^{-1}) by lablab bean under different treatments, cultivation practices (CP and CF), Control (average of CP and CF only), lime (L), organic (OF) and inorganic (IF) fertilizer applications including foliar zinc (Zn_1) and no-zinc (Zn_0) applications.*

Treatments		Sampling date/Total P-uptake (kg ha^{-1})		Sampling date/Total Zn-uptake (kg ha^{-1})	
		20-Feb-10	**14-Jan-11**	**20-Feb-10**	**14-Jan-11**
Cultural Practices	**CP**	2.44	0.39	0.031	0.007
	CF	5.15	0.90	0.083	0.018
Soil amendments applications	**Control**	1.90	0.25	0.028	0.007
	L	2.62	0.65	0.032	0.011
	OF	3.61	0.92	0.060	0.015
	IF	6.72	0.75	0.106	0.014
Zinc applications	**Zn_1**	4.64	0.86	0.070	0.016
	Zn_0	2.55	0.42	0.040	0.009

Table 4.3.3 shows that the amounts of plant- uptake phosphorus (total P-uptake) per growing area under furrow cultivation (CF) were 5.15 and 0.90 kg ha^{-1} which were higher than total P-uptake at 2.44 and 0.39 kg ha^{-1} under conventional planting (CP) during the 1st and the 2nd experimental year.

The amount of total P-uptake values given by inorganic fertilizer (IF) was the highest at 6.72 kg ha^{-1} compared to the 2nd, the 3rd high and the lowest total P-uptake which were 3.61, 2.62, and 1.90 kg ha^{-1} , given by organic fertilizer (OF), lime (L), and Control (average of CP or CF only) respectively in the 1st year. The total P uptake by lablab bean in the 2nd year also showed similar trends to the 1st year results, but the amount of total P-uptake values obtained in the 2nd year were much smaller than those obtained in the 1st year. In addition, foliar zinc spray (Zn_1) also gave higher amount of total P consumption than no zinc (Zn_0) spray. The amount of P- uptake in the 2nd year was very low compared to the 1st year results, due to the long drought period after lablab bean planting in the 2nd year experiment, leading to pour crop development, as described in 4.3.1.

The effects of the studied treatments on total Zn-uptake by lablab bean during 2 experimental years presented in Table 4.3.3 show similar trends to the results of total P-uptake in plant. However, the amounts of total Zn consumptions by plant under all treatments were very small values which could be negligible.

4.3.3 Total dry matter and seed yield

The single effects of each studied treatment on total dry matter and seed yield of lablab bean were shown in Table 4.3.4. While the effects of each cultural practice (CP and CF), applied organic and inorganic fertilizers (OF and IF) including combination effects of cultivation practices and soil amendments applications (CP-L, CP-OF, CP-IF, CF-L, CF-OF and CF-IF) on total dry matter and seed yield of lablab bean are presented in Figures 4.3.6 and 4.3.7 respectively.

(i) Effects of cultivation practices on total dry matter and seed yield of lablab bean

Table 4.3.4 and Figures 4.3.6- 4.3.7 show that total dry matter and seed yield of lablab bean in CF plot were significantly higher than those in CP plot. Total dry matters of lablab bean produced under CF and CP in the 1st year experiment were 1,631 and 839 kg ha^{-1} and in the 2nd year trial were 523 and 315 kg ha^{-1} respectively. The total dry matter obtained in the 1st year were almost 3 times higher than the 2nd year because plant sampling period in the 2nd year was 1 month earlier than the harvesting period due to drought damages caused by the long duration of dryness after lablab bean sowing in 2010. Particularly, lablab bean growing was limited under available water deficiency during vegetative-flowering stage in 2010, leading to poor crop development and incomplete total biomass production. This indicated that, the amount and distribution of rainfall are the most important factor that limits and governs crop growth under highland rainfed cultivation.

Therefore, the better rain-water harvested treatment like CF could give the higher crop development or total dry matter production and seed yield of lablab bean than those given by the high runoff treatment like CP significantly. Seed yield obtained in the 1st year trial in CF plot was 844 kg ha^{-1} which was approximately twice of 407 kg ha^{-1} gained in CP plot (Table 4.3.4)

Because in CF plot could harvest and store water within soil profile higher than those in CP plot (Panomtaranichagul and Narubarn, 2008), these amount of soil water was benefit to plant at early-dry season. Therefore, lablab been under CF had better water used which related to get higher total dry matter and yield than under CP.

Table 4.3.4 *Mean values of total dry matter and seed yield of lablab bean under conventional planting (CP) and furrow cultivation (CF), Control (average of CP and CF), lime (L), organic (OF) and inorganic fertilizer (IF) applications including foliar zinc (Zn_1) and no-zinc (Zn_0) spray.*

	Sampling date	Cultural Practices		LSD-1 P<0.05	Lime and fertilizers applications				LSD-2 P<0.05	Foliar-Zn spray		LSD-3 P<0.05
		CP	**CF**		**Control**	**L**	**OF**	**IF**		**Zn_1**	**Zn_0**	
Total dry matter ($kg\ ha^{-1}$)	**20-Feb-10**	839b	1,631a	**104**	592d	841c	1,337b	2,169a	**107**	1,435a	1,034b	**154**
	14-Jan-11	315	523	**ns**	220c	404b	589a	464ab	**163**	524a	314b	**167**
Seed Yield ($kg\ ha^{-1}$)	**20-Feb-10**	407b	844a	**147**	286d	409c	666b	1,140a	**72**	708a	543b	**110**

LSD-1, LSD-2 and LSD-3 are the least significant differences of the means, caused by different cultivation practices, applications of lime, organic/inorganic fertilizers and zinc application respectively, for comparison at P < 0.05

a, b, c and d represent differences between the means; ns : is none significant differences of the means.

(ii) ***Effects of lime, organic and inorganic fertilizers applications on total dry matter and seed yield of lablab bean***

Table 4.3.4 also shows that all applied soil amendments (Control, L, OF and IF) were significantly different from each other in giving total dry biomass and seed yield of lablab bean in both experimental years. The amounts of total dry matter and seed yield of lablab bean produced in the 1st year, were the highest at 2,169 and 1,140 kg ha^{-1}, under applied inorganic fertilizer (IF) and were the 2nd high at 1,337 and 666 kg ha^{-1}, under organic fertilizer application (OF) respectively. While the 3rd high and the lowest productions of lablab bean dry matter and yield were 841 and 409 kg ha^{-1}, under liming (L) and were 592 and 286 kg ha^{-1} under Control (average of CP and CF only) respectively (Table 4.3.4 and Figure 4.3.7). Applications of Control, L, OF and IF in the 2nd year gave similar trends of total dry biomass production of lablab bean as given in the 1st year trial. The amounts of lablab bean total dry matter produced under applications of OF, IF, L and control were 589, 464, 404 and 220 kg ha^{-1} which were the highest, the 2nd, the 3rd and the lowest of total dry matter values respectively (Table 4.3.4 and Figure 4.3.6b).

(iii) ***Effects of foliar zinc application on total dry matter and seed yield of lablab bean***

Table 4.3.4 also shows that the total dry matter and seed yield production of lablab bean under foliar Zn spraying (Zn_1) were significantly higher than those under no Zn application (Zn_0). Total dry matter and seed yield produced in the 1st year (harvest on 20 February, 2010) under Zn_1 were 1,435 and 708 kg ha^{-1}, and under Zn_0

were 1,034 and 543 kg ha^{-1} respectively. Whereas total dry matter obtained in the 2nd year under Zn_1 and Zn_0 were 524 and 314 kg ha^{-1} respectively.

These results were corresponded to the research work of Movahhedy-Dehnanavy et al. (2009), which showed that foliar Zn spray tended to improve the seed yield and quality of oil plant grown under the drought stress, because zinc promote nitrogen and phosphorus uptake, it is important in the synthesis of tryptophane, a component of some proteins and a compound needed for the production of growth hormone (auxin) and seed forming.

The above results revealed that furrow cultivation (CF), foliar zinc spray (Zn_1) and fertilizer applications (OF/IF) gave better crop growth and higher seed yield production of lablab bean than conventional planting (CP), no foliar Zn (Zn_0) spray and no fertilizer applications. These results indicated that water is the most important limiting factor for crop production in the highland rainfed-agricultural system. The 2nd important factor is soil fertility or nutrient availability. Foliar Zn spraying is an optional factor for improving crop development and yield. Therefore, applied inorganic fertilizer in cultivated furrow with foliar zinc spray (CF+IF+Zn_1) gave the highest total dry matter and seed yield production of lablab bean at 3,769 and 1,866 kg ha^{-1} respectively, whilst conventional planting without any soil amendment (CP) gave the lowest total dry matter and seed yield productions at 347 and 189 kg ha^{-1} respectively in the 1st year trial (Figure 4.3.6a and 4.3.7).

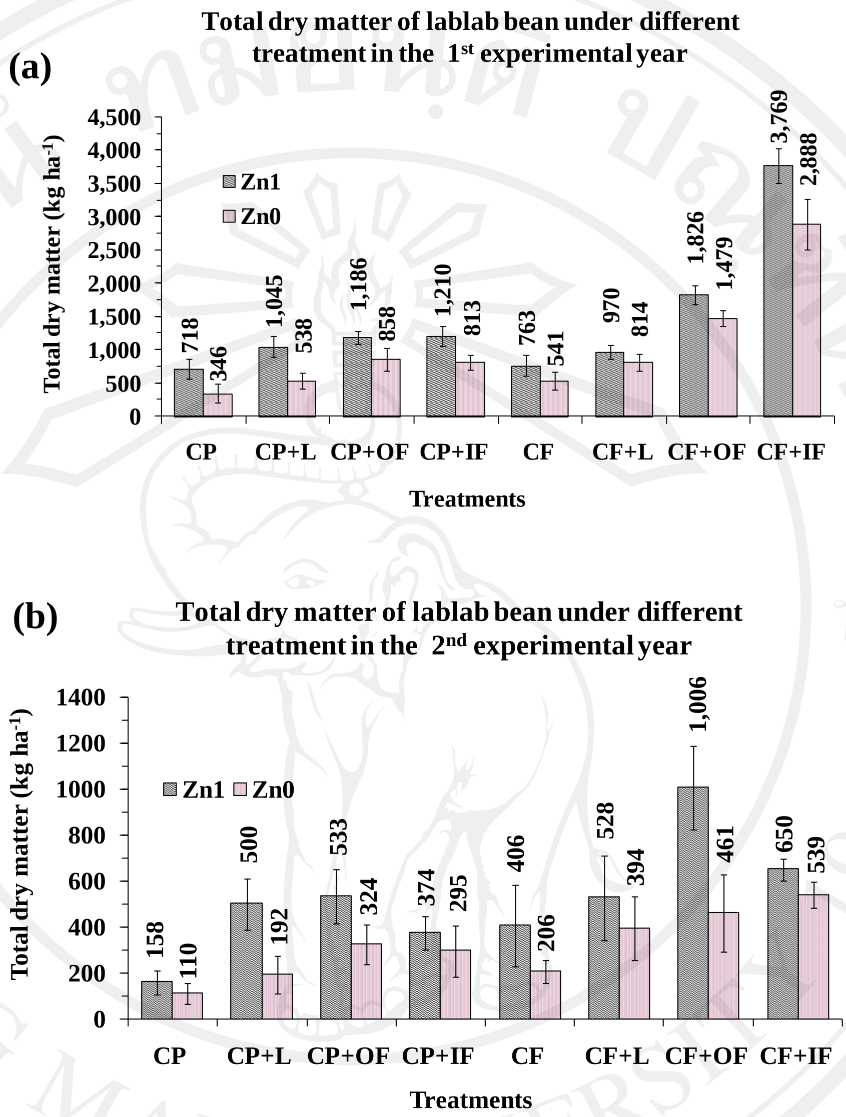


Figure 4.3.6 *The interaction effects of cultivation practices (CP and CF), soil amendments (L, OF, and IF), foliar zinc (Zn_1) and no zinc (Zn_0) applications on total dry matter of lablab bean in (a) the 1st and (b) the 2nd experimental year.*

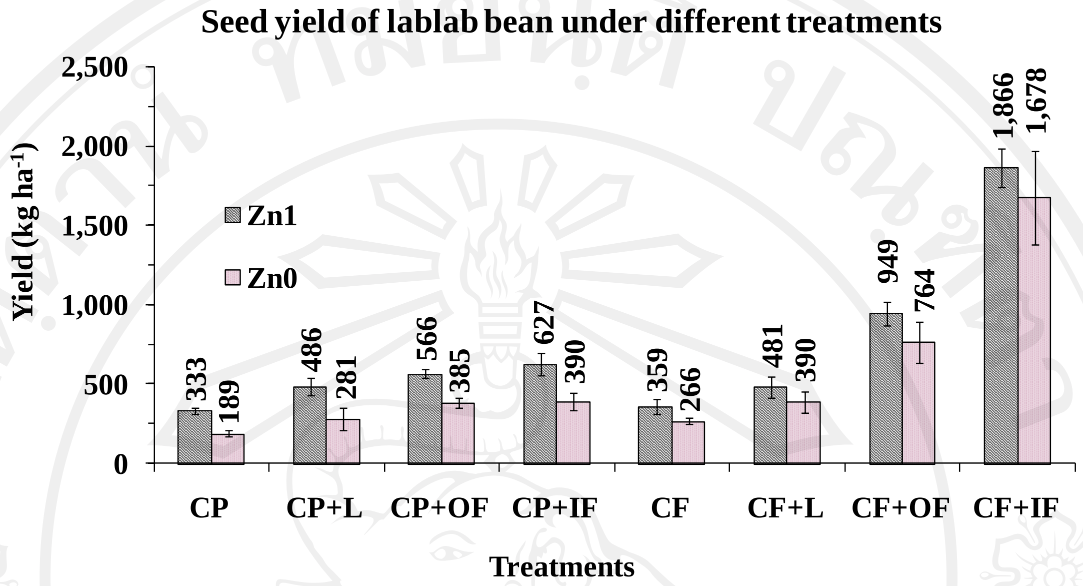


Figure 4.3.7 *The interaction effects of cultivation practices (CP and CF), soil amendments (L, OF, and IF), foliar zinc (Zn_1) and no zinc (Zn_0) applications on seed yield of lablab bean in the 1st year experiment.*

The effects of soil amendment applications on crop total biomass and yield production were more effective under CF than those under CP. Furrow cultivation with applications of inorganic fertilizer (CF+IF), organic fertilizer (CF+OF), and lime (CF+L) gave the average seed yield productions of lablab bean at 348%, 180%, and 113% higher than those given by conventional planting with applications of inorganic fertilizer (CP+IF), organic fertilizer (CP+OF), and lime (CP+L) respectively.