Fertilizer Sector Improvement (FSI+) in Burma

REPORT ON OMISSION POT TRIALS FOR 2017-18 SEASONS

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Introduction

IFDC is implementing the Fertilizer Sector Improvement (FSI+) project, a five-year project funded by USAID ending in September 2019. Increased income and food security of smallholder farmers in rice-based farming systems through improved technology are the primary goals.

IFDC has considerable experience with the introduction of urea deep placement (UDP) and balanced fertilizer management in rice crops. This includes application of secondary and micronutrients. In relation to that and to initiate a site-specific nutrient management (SSNM) approach, IFDC established omission pot trials and nutrient rate trials within the rice-rice and rice-gram cropping system starting in the 2016 wet season to define the recommendations to be extended by extension workers.

Objective

- To identify nutrient deficiencies in the soil type of the project area.
- To initiate SSNM to make a recommendation for the specific site/location/soil.

Materials and Methods

Soil Sampling

The soil samples were taken from a specific area of a farmer's field in a location that was representative of a large rice-growing area within the project region. Starting from the 2016 wet season, eight locations from the Yangon, Bago and Ayeyarwaddy regions had been selected for omission pot trials:

1. Gyoe Phyu Village, Taikkyi, Yangon Region.
2. Gway Dauk Kwin Village, Letpadan, Bago West Region.
3. Research Station, Aungban, Kalaw, Southern Shan State.

4. Paw Daw Mu Village, Kangyidaunt, Ayeyarwaddy Region.
5. Kanyin Gae Village, Kyaiklat, Ayeyarwaddy Region.
6. Nyaung Thone Bin Village, Thanlyin, Yangon Region.
7. Thar Kwin Village, Einme, Ayeyarwaddy Region.
8. Nyaung Zin Village, Zigone, Bago (West) Region.

Soil samples were taken at a depth of 0-20 cm. Subsamples were collected from seven locations within the field in a zigzag pattern to ensure a representative soil sample; sampling was not done in dead furrows or wet spots or areas near main bunds, trees, manure heaps, or irrigation channels. Surface litter and foreign materials (roots, stones, pebbles, and gravel) at each sampling spot were removed prior to collecting samples.

Preparation of Soil Samples

Soil samples were air-dried immediately after sampling on a plastic sheet in the greenhouse. The air-dried soil samples then were crushed manually using a wooden pestle and passed through a 1-mm nylon sieve to produce a fine homogenized powder at a particle size of <1 mm. Gravel and debris were removed. A subsample was reserved for determination of pH, water-holding capacity, and basic soil fertility parameters using a soil analysis kit.

Experimental Design

The experiment was set up in a completely randomized block with a total of 48 experimental units (12 treatments * 4 replications). Table 1 lists the treatment descriptions. Each treatment was replicated four times. Each replicate was organized on a separate bench in the greenhouse. The sample of randomization is shown in Figure 1. The experimental units were rotated randomly once every week in the greenhouse to allow each unit equal sunlight and shade.

Table 1. Treatments of Omission Pot Trials in the Greenhouse

Trt. No.	Treatment Description
1	All (N, P, K, Ca, Mg, S, Zn, B, Mo, Cu, Fe, Mn)
2	(N, P, K, Ca, Mg, S, Zn, B, Mo) or -(Cu, Fe, Mn)
3	All (-N)
4	All (-P)
5	All (-K)
6	All (-Ca)
7	All (-Mg)
8	All (-S)
9	All (-Zn)
10	All (-B)
11	All (-Mo)
12	Control

Rep 4			Rep 3		
-S	-N	-Zn	-N	-Mg	-Ca
Control	-K	-Ca	-Zn	-(Cu, Fe, Mn)	All
-Mo	All	-(Cu, Fe, Mn)	-K	-B	-S
-Mg	-B	-P	Control	-P	-Mo
Rep 1			Rep 2		
-S	-(Cu, Fe, Mn)	-Mg	-B	-Mg	All
Control	-Mo	All	-(Cu, Fe, Mn)	-N	-Ca
-P	-B	-N	-P	Control	-S
-Zn	-K	-Ca	-Zn	-K	-Mo

Note: Experimental units were rotated randomly once in every week within replication.

Figure 1. Randomization of Treatments

Setup and Management of the Trials

The experiment was conducted in the greenhouse constructed within the FSI+ Project Office Compound in Yangon.[1] Maize was used as the test plant (sweet corn seeds and hybrid corn seeds available in the local market) because of its well-characterized responses to nutrient deficiencies, as well as its rapid growth and uniform development. Plastic pots with a 20-cm diameter were lined with plastic bags, to prevent nutrient leaching, and filled with 2 kg of the air-dried prepared soil. Nutrients were applied in solution form to the soil in pots for the 11 treatments: All, -(Cu, Fe, Mn), -N, -P, -K, -Ca, -Mg, -S, -Zn, -B, and -Mo. All nutrients were applied into the pots with complete nutrients (All treatment). The minus nutrient treatments omitted the nutrient specified but contained all others. The nutrient stock solutions were prepared using single element analytical grade reagents with a concentration calculated to allow 10 mL to provide the required application rate for each treatment. When the elements were applied to each pot according to treatment, deionized water was added to get the weight of the pot to the calculated field capacity of the soil. Table 2 shows the nutrients, chemical forms, and nutrient rates for the omission pot trials. Nutrient solutions applied to particular treatments are given in Table 3.

Table 2. Nutrients, Chemical Forms, and Rates Used for Omission Pot Trials

Nutrient	Chemical Form	Nutrient Rate (kg/ha)
N	NH_4NO_3	200
P	KH_2PO_4, NaH_2PO4	80
K	KCl	100.645
Ca	$CaCl_2$	35
Mg	$MgSO_4.7H_2O$, $MgCl_2.6H_2O$	30
S	Na_2SO_4	40
Zn	$ZnCl_2$	5
B	H_3BO_3	1
Mo	$Na_2MoO_4.2H_2O$	0.4
Cu	$CuCl_2.2H_2O$	3
Fe	$FeNaEDTA.2H_2O$	5
Mn	$MnCl_2.4H_2O$	3

Maize seeds selected to standard weight were germinated prior to planting. Five germinated seeds were sown in each pot. Pots were watered (by weight) as often as necessary to maintain the soil moisture at approximately 80-85% of field capacity throughout the growing period.

[1]The greenhouse was built with a raised concrete floor and a wooden structure with open sides and clear transparent roofing. Plastic roll-up curtains were installed on each side to protect from wind and rain during storms.

Table 3. Nutrient Solutions of Chemicals Applied to Each Treatment of the Omission Pot Trials

Trt	Description	NH4NO3	KH2PO4	NaH2PO4	KCl	CaCl2	MgSO4.7H2O	MgCl2.6H2O	Na2SO4	ZnCl2	H3BO3	Na2MoO4.2H2O	CuCl2.2H2O	FeNaEDTA.2H2O	MnCl2.4H2O
1	ALL	YES	YES			YES	YES			YES	YES	YES	YES	YES	YES
2	NPKSCaMgZnBMo	YES	YES			YES	YES			YES	YES	YES			
3	Minus-N		YES			YES	YES			YES	YES	YES			
4	Minus-P	YES			YES	YES	YES			YES	YES	YES			
5	Minus-K	YES		YES		YES	YES			YES	YES	YES			
6	Minus-Ca	YES	YES				YES			YES	YES	YES			
7	Minus-Mg	YES	YES			YES			YES	YES	YES	YES			
8	Minus-S	YES	YES			YES		YES		YES	YES	YES			
9	Minus-Zn	YES	YES			YES	YES				YES	YES			
10	Minus-B	YES	YES			YES	YES			YES		YES			
11	Minus-Mo	YES	YES			YES	YES			YES	YES				
12	CONTROL														

Procedure for Adding Nutrients and Soil

1. The nutrients were added one at a time, using a glass pipette to accurately measure 10 mL of each stock solution. A separate pipette was used for each solution to prevent cross-contamination.
2. After all nutrient stocks were added, the pot was brought to field capacity by weight using deionized water.

Harvest, Measurement, and Data Collection

Harvesting was done by cutting from the base of the plant, and stem height was measured as the length from the base of the plant to the apex after four to five weeks of growth. Stem height and weight of the above-ground part of the plants were recorded. Fresh weight was taken directly after harvest, and dry weight was determined after oven drying at 70°C for 24 hours. Data were analyzed as a randomized complete block design using R-software, and a mean comparison was made by Bonferroni test at $P_{(0.05)}$ level.

Results and Discussion

1. Gyoe Phyu Village, Taikkyi, Yangon Region

Refer to Figure 2 and Table 4.

The omission pot trial using maize as the test plant with soil from Gyoe Phyu, Taikkyi, revealed significant differences of dry biomass weight among treatments. The control treatment had the second lowest biomass weight (3.3 g). The -Mg treatment had the highest biomass weight (38.5 g), which was significantly more than the other treatments except for the "All" treatment. The dry biomass weights of the -Ca, -Zn, -Mo, -(Cu, Fe, Mn), and -B treatments were significantly lower than the -Mg treatment but not significantly different from the "All" treatment. Therefore, Mg, Ca, Zn, Mo, Cu, Fe, Mn, and B were not deficient in the test soil. The -P treatment had the lowest dry biomass weight (2.0 g) among the treatments, even lower than the control treatment. Therefore, P was the most limiting factor of the test soil. The -S treatment had a dry biomass weight (4.2 g) that was not statistically different from that of the control plot. Sulfur was, therefore, the second most limiting element in the soil. The dry biomass weight of the -N treatment (5.5 g) was higher than the -P, -S, and control treatments although not statistically different. This indicates that N was also limited in the study soil. The -K treatment had a significantly higher dry biomass weight (12.9 g) than the control, -P, and -S treatments, but it was not significantly different than the -N treatment. It was significantly lower than those of the "All", -Cu, -Fe, -Mn, -Ca, -Mg, -Zn, -B, and -Mo treatments. K was, therefore, deficient, and application was needed on the test soil. Thus, the results indicate that P, S, N, and K were limiting in the test soil, with P being the most limiting element and K the least limiting element. Deficiency symptoms of N, P, K, and S are shown in Photo 1.

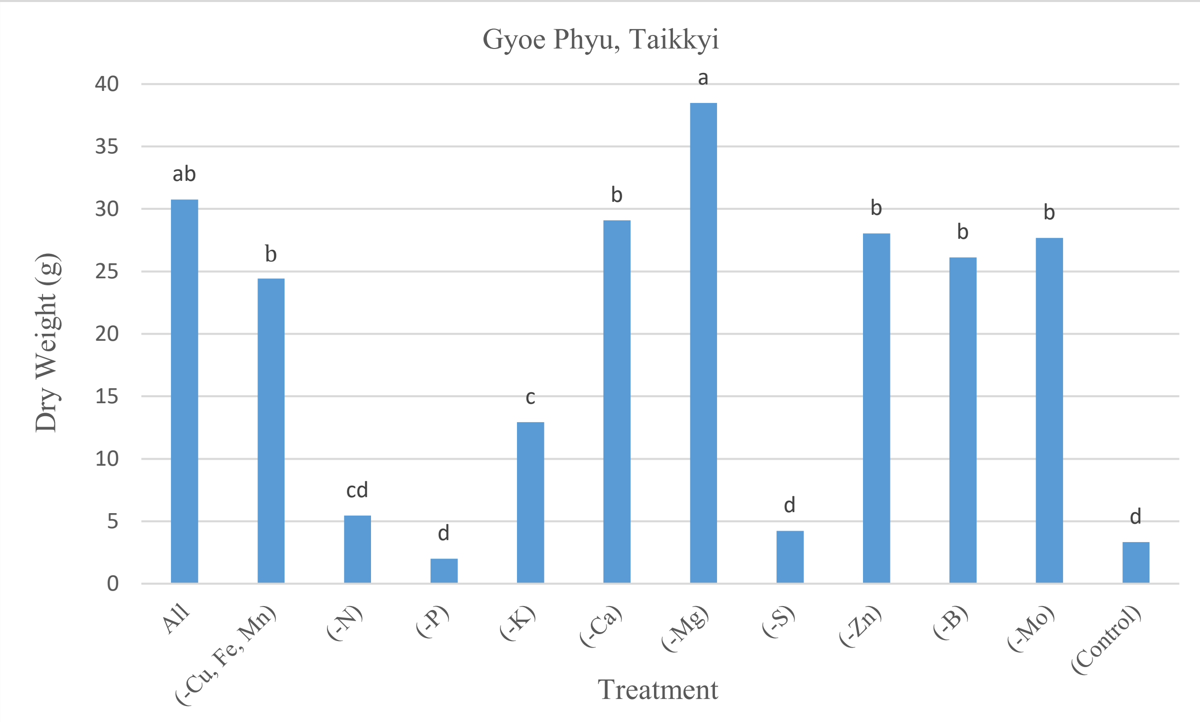

Figure 2. Relative Dry Biomass Weight of Treatments of Nutrient Omission Pot Trial of the Study Soil from Gyoe Phyu, Taikkyi (columns with the same letter[s] do not differ significantly at $P_{(0.05)}$ by Bonferroni test)

Photo 1. N, P, K, and S Deficiency Symptoms from the Omission Pot Trial of the Soil from Gyoe Phyu Village, Taikkyi

2. Gway Dauk Kwin Village, Letpadan, Bago West Region

Refer to Figure 3 and Table 4.

The omission pot trial with soil from Gway Kauk Kwin, Letpadan, showed significant differences among treatments. The treatment with all nutrients produced the highest biomass weight (21.5 g). The -(Cu, Fe, Mn) treatment showed the second highest dry biomass weight at 20.5 g. The dry biomass weight of the -P treatment had the lowest weight (2.0 g), and the control treatment had the second lowest weight at 3.5 g. Both were not statistically different and significantly lower than those of the other treatments. The -N treatment also produced a low biomass (6.9 g), which was not statistically different from that of the control treatment. P in the test soil was determined to be the most limiting element and N was the second most limiting. The treatments of -K and -S produced 8.5 g and 10.3 g dry biomass weights, respectively, which were statistically higher than that of the control treatment, but they were not significantly different than that of the -N treatment and were significantly lower than those of treatments with All, -(Fe, Cu, Mn), -Ca, -Mg, -Zn -B, and -Mo. Therefore, K and S were also deficient in the test soil. The deficiency of those elements can be ranked as P>N>K>S.

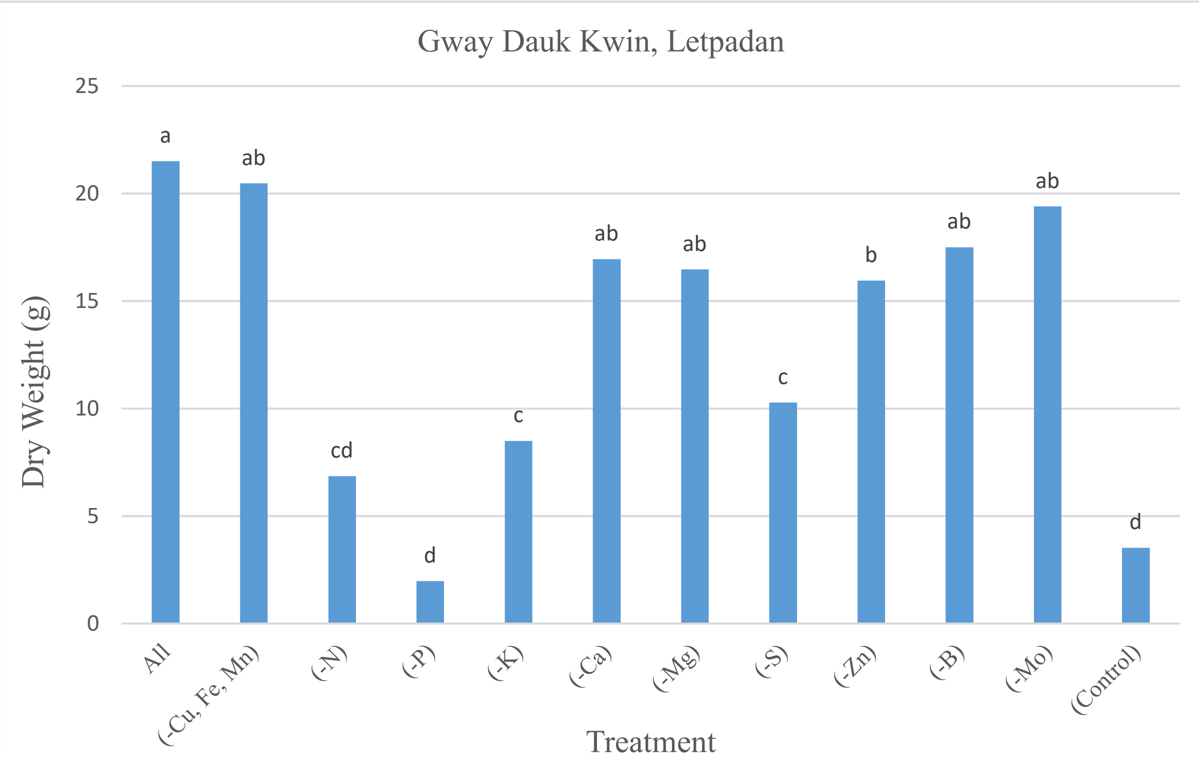

Figure 3. **Relative Dry Biomass of Treatments of Nutrient Omission Treatments of the Study Soil from Gway Dauk Kwin, Letpadan (columns with the same letter[s] do not differ significantly at $P_{(0.05)}$ by Bonferroni test)**

3. Aungban Research Station, Aungban, Kalaw, Shan State

Refer to Figure 4 and Table 4.

The analysis of variance (ANOVA) of the omission pot trial with soil from Aungban Research Station showed significant differences among treatments. The treatment that applied all nutrients had the highest dry biomass yield at 7.9 g. This was not statistically different from the dry biomass weights of treatments which omitted Ca, Mg, S, Zn, B, Mo, and (Cu, Fe, Mn). The dry biomass weights of those treatments ranged from 6.4 g to 7.7 g. Therefore, Ca, Mg, S, Zn, B, Mo, Cu, Fe, and Mn were not deficient in the test soil. The -P treatment had the lowest dry biomass weight, which was significantly lower than any other nutrient-applied plot. It was even lower than that of the control plot, which produced 2.7 g dry biomass although not significantly different. Therefore, P was the only limiting element among all essential elements. The -K and the -N treatments produced 5.6 g and 5.7 g dry biomass, respectively, which were significantly higher than those of the -P and control treatments and not significantly different from the other omission treatments except the -(Cu, Fe, Mn) treatment; they were significantly lower than that of the "All" treatment. Therefore, K and N were not as deficient as P but they seemed insufficient in the test soil, with K being a little more limiting than N.

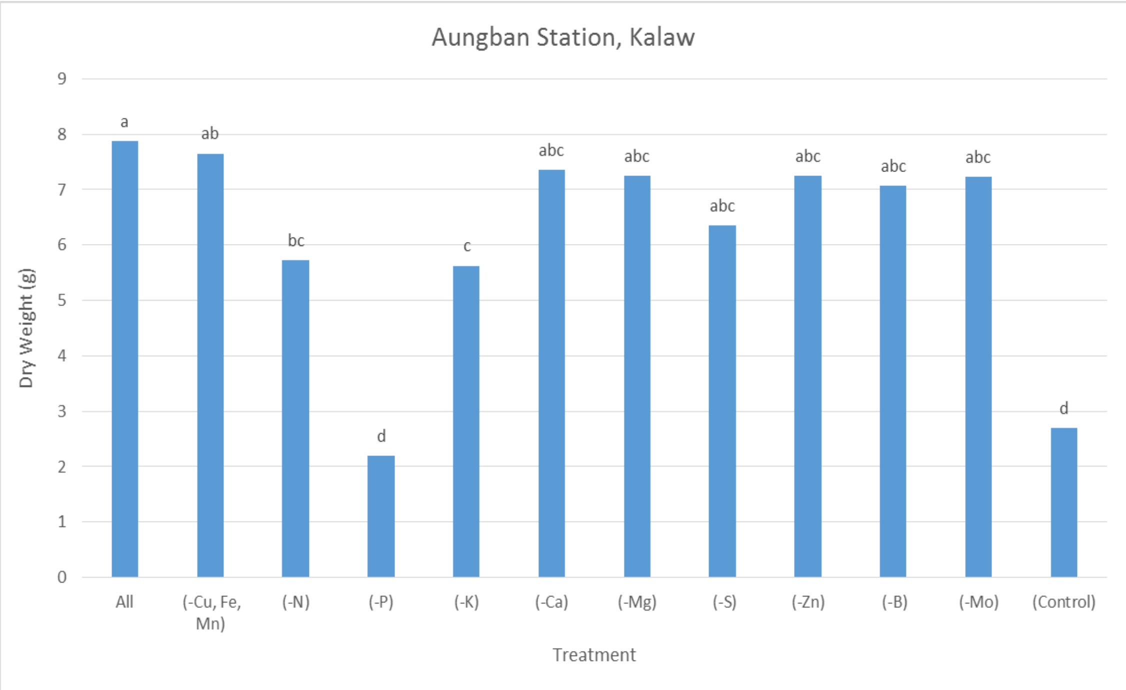

Figure 4. Relative Dry Biomass Weight of Maize in Various Nutrient Omission Treatments of the Study Soil from Aungban Station, Kalaw (columns with the same letter[s] do not differ significantly at $P_{(0.05)}$ by Bonferroni test)

4. Paw Daw Mu Village, Kangyidaunt, Ayeyarwaddy Region

Refer to Figure 5 and Table 4.

The omission pot trial with soil from Paw Daw Mu revealed significant differences among treatments. The -P, control, and -N treatments produced significantly lower dry biomass weights than any other treatment. The dry biomass weight of the -P treatment was the lowest at 1.7 g, followed by the control treatment at 1.8 g. The -N treatment produced 2.6 g dry biomass weight. The dry biomass weights of these three treatments were not statistically different. The dry biomass weight of the other treatments ranged from 7.4 g to 9.3 g. The treatment that applied all nutrients produced the highest dry biomass weight at 9.3 g. The -K treatment produced the lowest dry biomass weight of the set at 7.4 g. All of these treatments were not significantly different. The results clearly indicate that only P and N were deficient in the soil from Paw Daw Mu, Kangyidaunt, and that other plant nutrients were not deficient. N and P deficiency symptoms are shown in Photo 2.

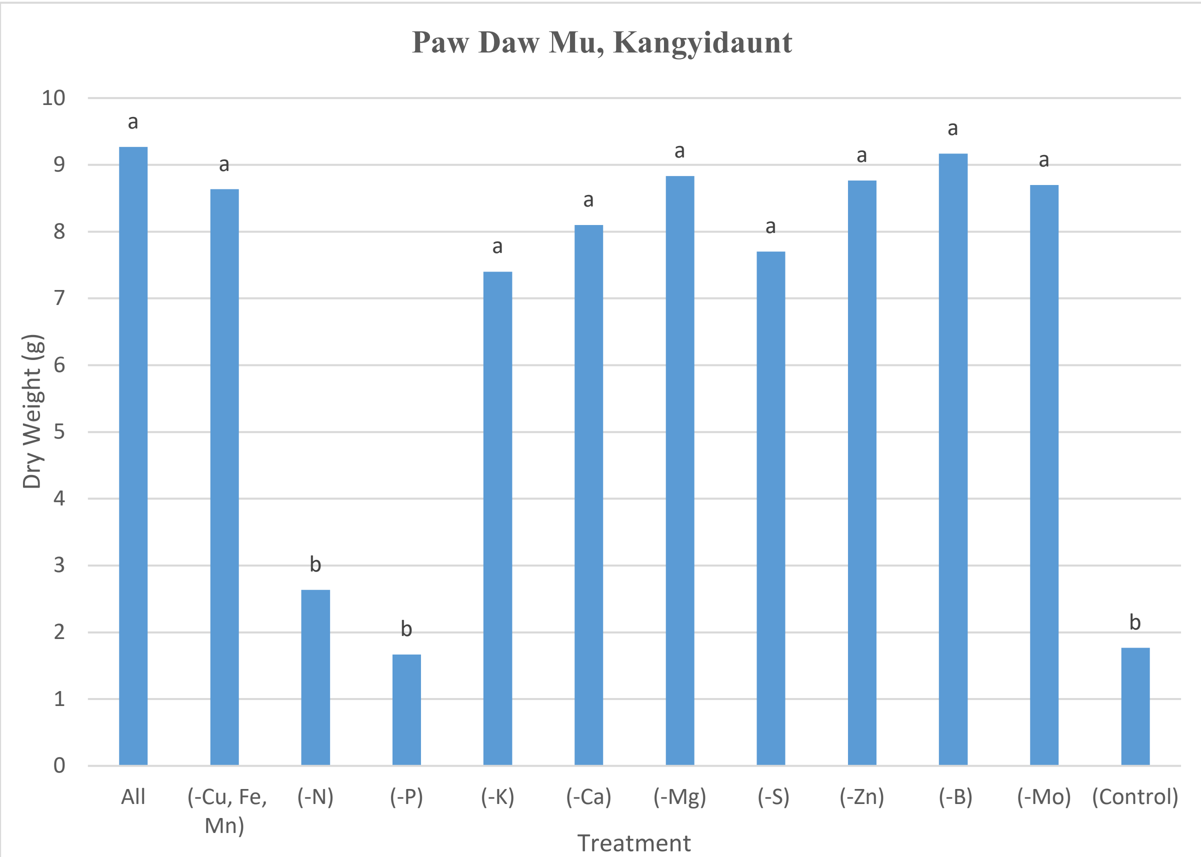

Figure 5. Relative Dry Biomass Weight of Maize Plants from Various Nutrient Omission Treatments of the Study Soil from Paw Daw Mu Village, Kangyidaunt Township (columns with the same letter[s] do not differ significantly at the 5% level by Bonferroni test)

Photo 2. **N and P Deficiency Symptoms from the Omission Pot Trial of Soil from Paw Daw Mu Village, Kangyidaunt**

5. Kanyin Gae Village, Kyaiklat, Ayeyarwaddy Region

Refer to Figure 6 and Table 4.

The omission pot trial with soil from Kanyin Gae using maize as a test plant showed significant differences among treatments. The -P treatment produced the significantly lowest dry biomass weight at 1.8 g. This was not significantly different from the dry biomass weight of 2.0 g produced by the control plot. The dry biomass weights of other treatments ranged from 5.8 g to 7.4 g. The treatment that applied all nutrients produced 6.5 g dry biomass, which was not statistically different than other omission treatments except for the -P and the control treatments. The -B treatment produced the highest dry biomass weight at 7.4 g but was not significantly different than the treatment applying all nutrients. The -S treatment produced a dry biomass weight of 5.8 g, and the -N treatment produced 5.9 g. These were not statistically different than the treatment applying all nutrients. Therefore, the test soil from Kanyin Gae, Kyaiklat, was deficient only in P.

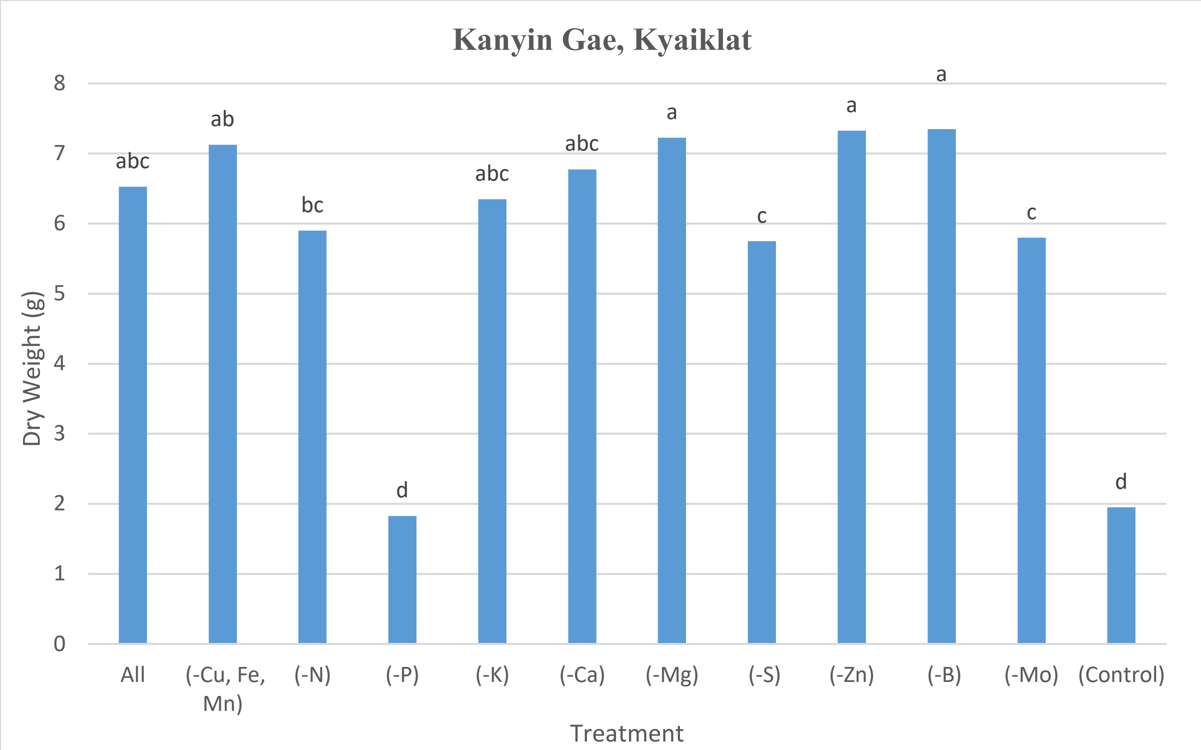

Figure 6. Relative Dry Biomass Weight of Maize Plants from Various Nutrient Omission Treatments of the Study Soil from Kanyin Gae Village, Kyaiklat Township (columns with the same letter[s] do not differ significantly at 5% level by Bonferroni test)

6. Nyaung Thone Bin Village, Thanlyin, Yangon Region

Refer to Figure 7 and Table 4.

The omission pot trial with soil from Nyaung Thone Bin, Yangon, revealed that the dry biomass weights of the -K, -Ca, -Mg, -S, -Zn, -Mo, -(Cu, Fe, Mn), and -B treatments were not significantly different from that of the "All" treatment. The dry biomass weights of those treatments ranged from 13.0 g to 15.7 g. The treatment that applied all nutrients had a dry biomass weight of 14.1 g. The control plot had the lowest dry biomass weight at 2.8 g. The -N treatment produced the second lowest biomass weight at 3.8 g, followed by the -P treatment at 4.0 g. These three treatments were not statistically different, but they were significantly different from the "All" treatment and the other nutrient omission treatments, which produced significantly higher dry biomass weights. The large difference in results clearly revealed two different categories; one was the deficient group of nutrients (N and P) and the other was the remaining group of nutrients that were not deficient.

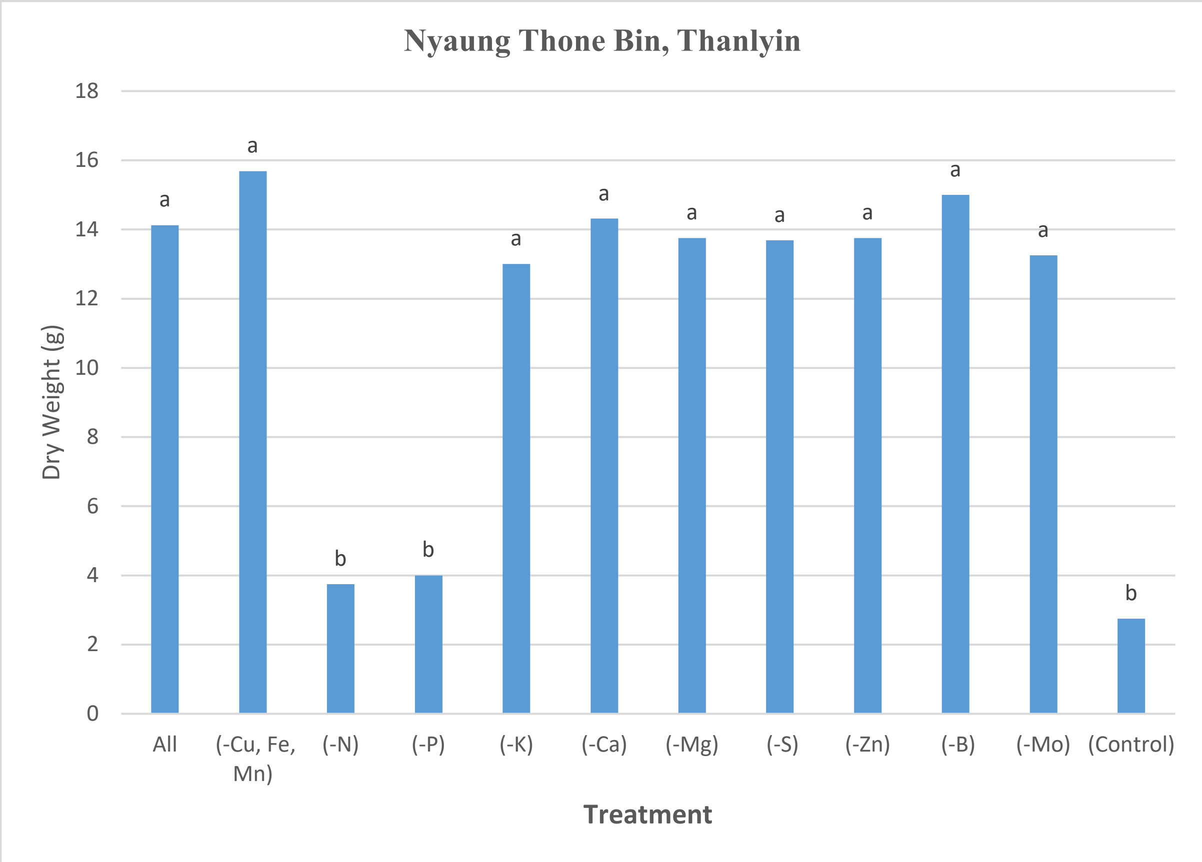

Figure 7. Relative Dry Biomass Weight of Maize Plants from Various Nutrient Omission Treatments of the Study Soil from Nyaung Thone Bin Village, Thanlyin Township (the same letters in various columns do not differ significantly at the 5% level by Bonferroni test)

Photo 3. **N Deficiency Symptoms (left) and P Deficiency Symptoms (right) from the Omission Pot Trial of Soil from Nyaung Thone Bin Village, Thanlyin**

7. Thar Kwin Village, Einme, Ayeyarwaddy Region

Refer to Figure 8 and Table 4.

According to ANOVA, the dry biomass weights of the omission pot trial of the soil from Thar Kwin, Einme, showed significant differences among treatments. The control treatment gave the lowest dry biomass weight at 20.2 g. It was the same as the dry biomass weight of the -P treatment (20.2 g). Therefore, P clearly was deficient in the test soil. The “All” treatment did not produce the highest dry biomass; it produced 44.5 g dry biomass. The highest dry biomass weight of 59.5 g was produced by the -Mo treatment. These were not significantly different. The dry biomass weights of the (Cu, Fe, Mn), K, Ca, Mg, S, Zn, and B omission treatments ranged from 43.3 g to 52.3 g and were not significantly different from that of the “All” treatment. Those elements therefore seemed not deficient in the test soil. The -N treatment produced 31.5 g dry biomass, which was significantly lower than the highest dry biomass weight (59.5 g). However, it was not significantly different from that (44.5 g) of the “All” treatment nor was it significantly different from that (20.2 g) of the control treatment. The N in the test soil was not sufficient for the plant, though it was not as deficient as P. P was the most limiting element and N was the second most limiting element in the test soil.

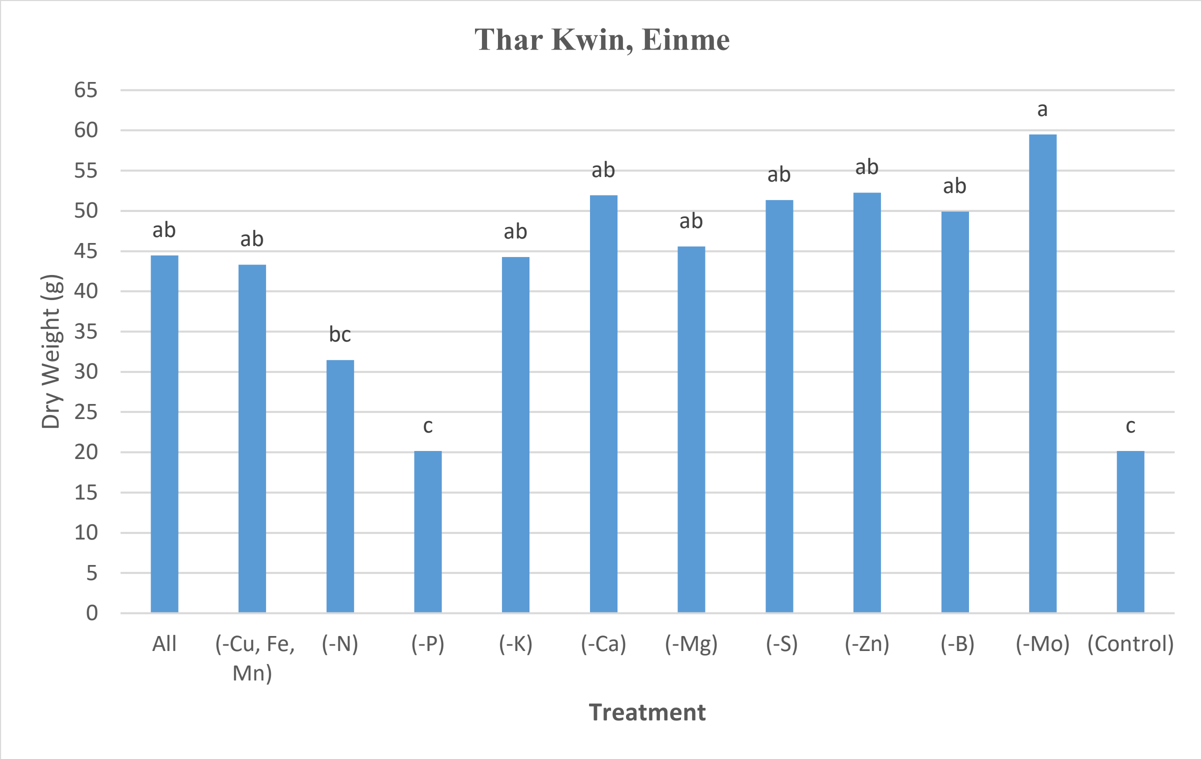

Figure 8. **Relative Dry Biomass Weight of Maize Plants from Various Nutrient Omission Treatments of the Study Soil from Thar Kwin Village, Einme Township (columns with the same letter[s] do not differ significantly at 5% level by Bonferroni test)**

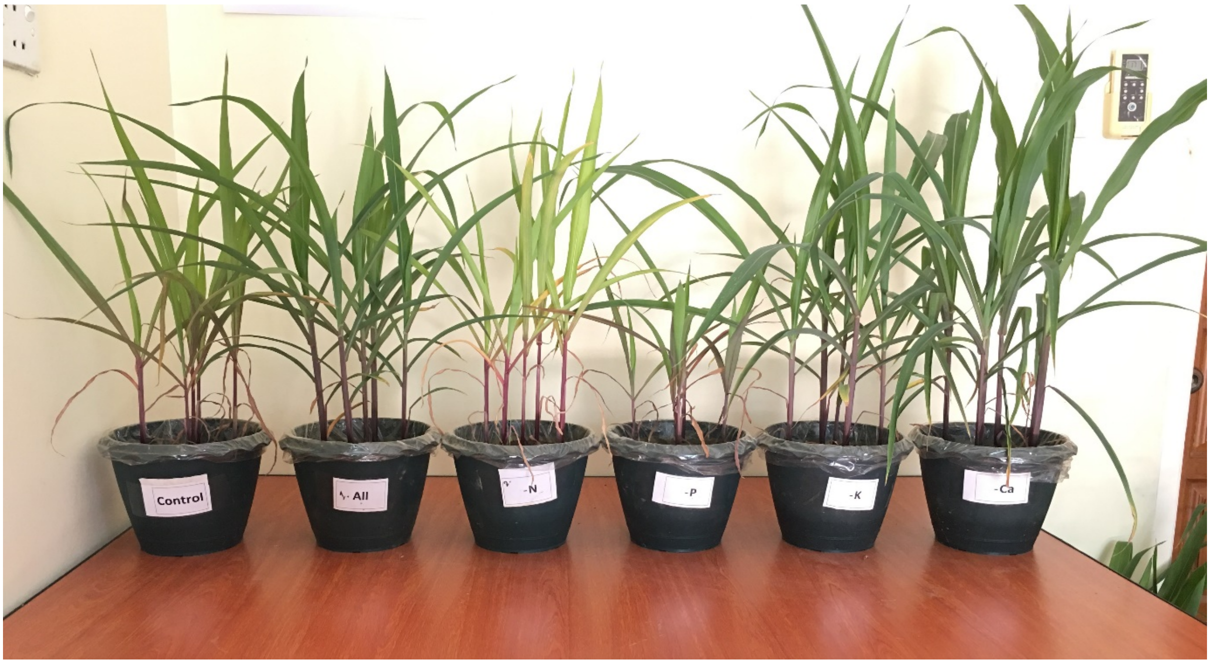

Photo 4. **N and P Deficiency Symptoms from the Omission Pot Trial of the Soil from Thar Kwin Village, Einme**

8. Nyaung Zin Village, Zigone, Bago (West) Region

Refer to Figure 9 and Table 4.

This soil was slightly acidic (pH 5.9) according to the soil pH test results. The ANOVA showed significant differences at $P_{(0.01)}$ among treatments. The control treatment had the lowest dry biomass weight at 6.1 g. The -N treatment had a slightly higher dry biomass weight (6.8 g) than the control treatment. The -P treatment produced 7.3 g of dry biomass. However, all of these treatments were not statistically different. Therefore, N and P were clearly deficient in the test soil. N seemed to be the most limiting element, followed by P. The dry biomass weight of the other treatments ranged from 10.9 g with the "All" treatment to the highest of 13.1 g with the -S treatment (Table 4). The ANOVA showed no difference among dry biomass weights of those treatments. Therefore, K, Ca, Mg, S, Zn, B, Mo, and (Cu, Fe, Mn) were not deficient in the test soil. The test soil has two clearly different categories of soil fertility; one is the deficient group (N and P), and the other is the remaining elements that are not deficient. A mean comparison of treatments is presented in Figure 9 and Table 4.

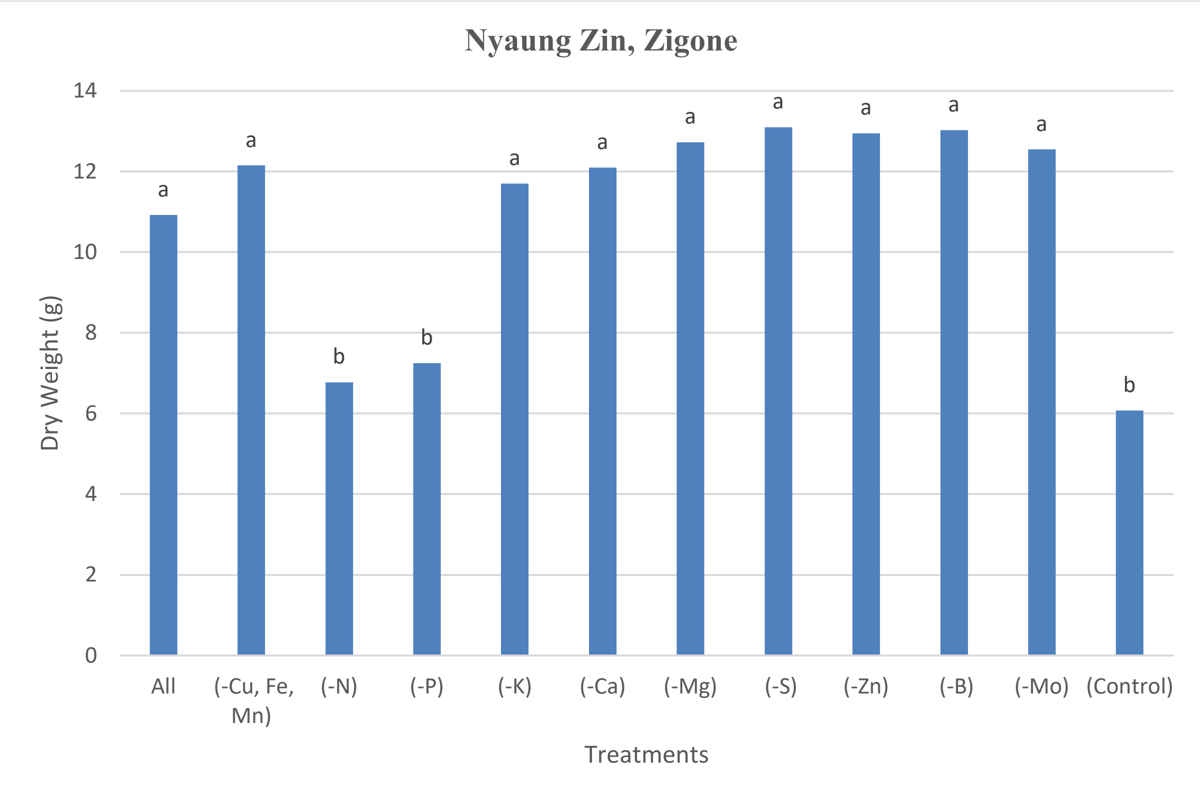

Figure 9. Relative Dry Biomass Weight of Maize Plants from Various Nutrient Omission Treatments of the Study Soil from Nyaung Zin Village, Zigone Township (columns with the same letter[s] do not differ significantly at the 5% level by Bonferroni test)

Photo 5. N and P Deficiency Symptoms from the Omission Pot Trial of the Soil from Nyaung Zin Village, Zigone

Conclusion

Nutrient assessment through omission pot trials provides the order and magnitude of the nutrient deficiency and is a simple method to determine the most limiting nutrients.

The results of omission pot trials of the eight soils sampled show that P is deficient in all of the test soils. The dry biomass weight of the -P treatment was as low as the control treatment in all test soils. P was found to be deficient even in the soils of Thanlyin and Kyaiklat, where progressive farmers have more knowledge about soil fertility and apply more fertilizer than typical smallholder farmers (Table 4). This could be due to the use of compound fertilizers, which may not replace all of the P used by crops.

The soil sample from the Aungban Research Station was from land with no history of a research trial. The sample was located at the back of the station but sown with maize in the last wet season and fertilized with urea and compound fertilizer. The plot could be considered just like a farmer's field. P deficiency was detected, and again, the amount of P applied as compound fertilizer appears to be less than what is needed.

N was found deficient in seven of the eight test soils – all except Kanyin Gae village, Kyaiklat. The farmer at Kanyin Gae is a seed grower and uses a high fertilizer rate, especially N. The magnitude of deficiency of N was a little less than that of P. However, N was found to be more limiting than P in Nyaung Thone Bin, Thanlyin, and Nyaung Zin, Zigone. The other deficient nutrients, according to the omission pot trials, were K and S. K was found to be deficient in three of the eight study soils and S in two of the eight soils. The sufficient amount of K in some farmers' soils could be due to the old cultural practice of burning rice stubble before growing the subsequent crop. But the results indicate that K is the next limiting element after P and N. Regarding fewer S deficiency results in test soils, some farmers are intentionally applying compound fertilizer with S, for example, 15:15:15+7S or urea fertilizer with sulfur. Fertilizer traders are intentionally introducing fertilizers with additional S to amend the alarming sulfur deficiency in farmers' fields. These elements are often deficient in FSI+ project areas where less compound fertilizer is applied at lower rates in a rice-rice cropping pattern.

According to the omission pot trials, P, N, often K, and sometimes S are expected to be deficient in most farmers' fields. The P and N deficiencies are due to imbalanced fertilization using compound fertilizer with various ratios that deliver insufficient individual elements. The deficiencies are likely to occur in areas where a rice-rice system is practiced. Better farmer education on balanced fertilization would help to increase crop yields and avoid soil mining and land degradation.

Table 4. Dry Biomass Weights of Treatments of Omission Pot Trials from Various Locations (mean dry biomass weights with the same letter[s] were not statistically different at the 5% level by Bonferroni test)

Treatment	Dry Biomass Weight by Location (g)							
	Gyoe Phyu Taikkyi	Gway Dauk Kwin Letpadan	Aungban Station Kalaw	Paw Daw Mu Kangyidaunt	Kanyin Gae Kyaiklat	Nyaung Thone Bin Thanlyin	Thar Kwin Einme	Nyaung Zin Zigone
All	30.8 ab	21.5 a	7.9 a	9.3 a	6.5 abc	14.1 a	44.5 ab	10.9 a
-(Cu, Fe, Mn)	24.4 b	20.5 ab	7.7 ab	8.6 a	7.1 ab	15.7 a	43.3 ab	12.2 a
-N	5.5 cd	6.9 cd	5.7 bc	2.6 b	5.9 bc	3.8 b	31.5 bc	6.8 b
-P	2.0 d	2.0 d	2.2 d	1.7 b	1.8 d	4.0 b	20.2 c	7.3 b
-K	12.9 c	8.5 c	5.6 c	7.4 a	6.4 abc	13.0 a	44.3 ab	11.7 a
-Ca	29.1 b	17.0 ab	7.4 abc	8.1 a	6.8 abc	14.3 a	51.9 ab	12.1 a
-Mg	38.5 a	16.5 ab	7.3 abc	8.8 a	7.2 a	13.8 a	45.6 ab	12.7 a
-S	4.2 d	10.3 c	6.4 abc	7.7 a	5.8 c	13.7 a	51.3 ab	13.1 a
-Zn	28.1 b	16.0 b	7.3 abc	8.8 a	7.3 a	13.8 a	52.3 ab	13.0 a
-B	26.1 b	17.5 ab	7.1 abc	9.2 a	7.4 a	15.0 a	49.9 ab	13.0 a
-Mo	27.7 b	19.4 ab	7.2 abc	8.7 a	5.8 c	13.3 a	59.5 a	12.6 a
Control	3.3 d	3.5 d	2.7 d	1.8 b	2.0 d	2.8 b	20.2 c	6.1 b