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Effects of Foliar and Soil Applied Fertilizers on Cambodian Rice

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Abstract:
Cambodian soils used for lowland rice cultivation are low in available nitrogen (N), phosphorus (P) and potassium (K), and have low organic matter content and low cation-exchange capacity. Soil application of fertilizersis mainly used for rice production in the country. Foliar fertilization is an efficient way to enhance rice growth and production, but is unknown for Cambodian rice and conditions. We aim to determine the effects of foliar plus soilapplied fertilizers on growth and yield of Senpidao rice variety (Oryza sativa L.). The experiment with randomised-completed block design was conducted with four replications for five different treatments and one control group in plots of 3m × 4m. Soil of the experimental plot was classified as Brown hydromorphics or Toul Samroung soils, which 100 kg N, 52 kg P_2O_5, 00 kg K_2O ha^{-1} are recommended for rice cultivation.In treatment 1 (T1), foliar fertilizer (FF) was solely applied; soil applied fertilizers (i.e. Urea, DAP-diammonium phosphate) were used to meet ¼, ½ and ¾ recommonded rate (RR) and suplemented with FF for T2, T3 and T4, respwctively; T5, full RR dose with no FF and T0, untreated control.In each plot, 19 days old rice seedlings were directly transplanted2-3 seedlings per hill, and 20cm × 20cm plant spacing. Urea and DAP were applied to soil at three stages (i.e. transplanting date, 25 DAT-days after transplanting, PI-panicle initiation). Foliar fertilizer was well dissolved into water (1 kg ha^{-1}) and sprayed on rice leaves twice, at 25 DAT and PI stage. We found all response variables generally increased with the amount of soil applied fertilizersin T2, T3 and T4, whereas ones in T4 and T5 were not significantlydifferent.Tiller numbers, panicle numbers per tiller, 1,000-grain weight and grain yield in T1 were significantly greater than T0.The findings suggest that improved grain yield (as measured by increased tiller numbers, panicle numbers and decreased panicle sterility) was due to foliar fertilization. The results of this study indicate that one-fourth of the soil-applied fertilizers could be substituted by foliar fertilization in rice cultivation in Cambodia.

Keywords: *Cambodian rice, foliar fertilizer, rice cultivation, Senpidao rice, soil applied fertilizer, Toul Samroung soils*

1. Introduction

Rice (*Oryza sativa* L.) is the most important crop in Cambodia, and represents the back bone of the country's economy.The average rice yield of 2.97 t $ha^{-1}$is much lower than the world average of 4.1 t ha^{-1} or the Asian average of 4.2 t ha^{-1} (FAO, 2011). The rate of applied fertilizers is the major factor involved in this low productivity (Seng, et al. 2001). For example, low available nitrogen (N), phosphorus (P) potassium (K), organic matter and cation-exchange capacity were found in most soils used for rice cultivation in rainfed lowlands of Cambodia (White et al., 1997). Although recommended rate of fertilizer application for Cambodian soil types exists (White et al., 1997), there is no specific type of fertilizer or combination of fertilizers that are recommended (Seng et al., 2001).Soilapplication of fertilizers isthe most common methodto supply essential nutrients to cropplants, which absorb the nutrients throughtheir roots and translocated to aerial parts.Foliar fertilization, which is absorbed by the cuticle leaf or the stomata then enter the cells in short time, is an alternative successful method to correct diagnosis of nutrient deficiency and enhance productioninplants (e.g. Fageria et al., 2009).An additonal advantagesis that other agrochemical can be applied in the same operation as tank mixes allowing saving in labor, machinery and energy cost (Gooding and Davies, 1992) or when soil application is ineffective due to immobilzation of soil applied nutrients, e.g. under extreme soil pH conditions (Truog, 1946) or soil moisture is limited (e.g. Vaidyanathon and Talibudeen, 1970).

Recent studies have shown that rice yield and quality can be increased and improved by foliar fertilization (e.g.Dario et al., 2014;Giacosa et al. 2014;Shaygany et al., 2014;Rehman et al., 2014). However, there is little known about the combination of foliar and soil applied fertilizers for rice production in Cambodia (Seng et al., 2001).We aim to dertermine the effects of foliar and soil applied fertilizers on agronomic traits of Senpidao rice. We hypothesized that the use of foliar fertilizationon rice would reduce by one-fourth the amount of soil applied fertilizers required.

2. Materials and Methods

2.1. Area and Condition

We conducted the experiment in the dry season (February – June) of 2012 at the Research and Training Farm (13°00'26.5"N; 103°18'49.0"E), University of Battambang (UBB), Cambodia. The soil of the experimental plot was classified as Brown Hydromorphics group by Crocker (1962) or Toul Samroung soils by White et al. (1997). The soil characteristics were described in Srean et al. (2012), and the climatic characteristics during the growing season are shown in Table 1.

Month	Rainfall (mm)	Evaporation (mm/day)	Maximum Temperature (^{0}C)	Minimum Temperature (^{0}C)	Wind Speed (m/s)	Humidity (%)
January	16.20	4.36	31.51	23.54	2.38	74.35
February	46.80	4.42	33.50	24.22	2.52	74.17
March	57.80	4.36	34.95	25.31	2.97	73.06
April	56.30	4.61	35.55	26.65	3.25	74.33
May	166.20	4.70	34.72	25.83	3.38	78.06
June	77.70	4.90	34.04	26.04	4.20	78.50
July	133.60	4.90	33.66	25.52	3.38	80.19

Table 1: Climate characteristics from January to July of 2012 were collected in the Vealbekchan Meteorology Station, where located about 13 km far away from the experimental site (PDOWRAM 2012)

2.2. Experimental Design

The experiment was conducted using randomized-completed block design with four replications in plots of 3 m × 4 m. The soils of the experimental plot were ploughed twice before separating it into 24 small plots. Senpidao rice variety was selected for this experiment because it is insensitive to photoperiod, early maturity (110 – 120 days of duration), and is an aromatic and high-value rice (CARDI, 2011). Rice seeds were soaked for 24 hours before sowing on seed beds with seed rate of 50 g m^{-2}. When the seedlings were 19 days old with 2 – 3 leaves per healthy seedling, they were transplanted - 2to3 seedlings per hill with plant spacing of 20 cm × 20 cm. They received intermittent wetting and drying during the vegetative phase. Soil and foliarapplied fertilizers were used for rice fertilization in each treatment. FF was well dissolved into water following rate of 1 kg ha^{-1} before spraying on rice leaves at around 10:00 in the morning. The treatment groups were designed based on RR of White et al. (1997) for Toul Samroung soils under irrigated condition (see Table 2). Soil-applied fertilizers (i.e. Urea and DAP) were used to complete the RR required; Urea and DAP were applied to soil at three stages (i.e. transplanting date, 25 DAT, PI); and foliar fertilizer was well dissolved into water (1 kg ha^{-1}) and sprayed on rice leaves twice at 25 DAT and PI stage.

	Treatment
T0	Untreated control
T1	FF
T2	¼ RR + FF
T3	½ RR + FF
T4	¾ RR + FF
T5	RR (full dose)

Table 2: Combination of foliar and soil applied fertilizers application for each treatment.
Note: RR is recommended rate (100 kg N, 52 kg P_2O_5, 00 kg K_2O ha^{-1}) according to White et al. (1997);
FF: foliar fertilizer (20%N, 30% P_2O_5, 20%K_2O + TE)

2.3. Data Collection and Analysis

To evaluate the agronomic traits of the rice plants in response to the foliar and soil applied fertilizerapplication, we randomly selected 15 plant hills per plot to measure plant height and number of tillers at the end of the experiment. Thirty panicles in each plot were measured to determine the number of grains per panicle and the panicle length. To measure grain yield, 4 m^2 in each plot was harvested, the grain weight was adjusted to 14% moisture level, and then converted to tons per hectareand 1,000-grain weight was also measured. To avoid pseudoreplication (Hurlbert, 1984), the data measured were averaged per plot for each replicate. We applied $\log_{10}$-transformation to all variables to satisfy the assumptions of the parametric statistical methods (i.e. normality, homoscedasticity and linearity). To test whetherthe mean differed among treatment groups for each response variable, we used analysis of variance (ANOVA) followed by Tukey's honestly significant difference (HSD) test (Abdi and Williams, 2010); and the differences were considered significant at $P< 0.05$, the P-values were adjusted for multiple comparisons. We used the 'ggplot2' R package (Wickham, 2011) to perform strip-chart for each response variable. The strip-chart was used instead of bar chart because it was suggested by Weissgerber et al. (2015) for small sample size studies. Statistical analysis was performed with the R software, version 3.1.3 (R Core Team 2015).

3. Results and Discussion

We found significant differences among treatment groups for all response variables for the agronomic traits ($P< 0.05$). Although the plant height (Fig. 1), number of tillers (Fig. 2), number of panicles per tiller (Fig. 3), number of panicles per tiller (Fig. 4), number of grains per panicle (Fig. 5), 1,000-grain weight(Fig. 6) or grain yield (Fig. 7)increased generally with increasing amount of soilapplied fertilizers, there was no significant difference between T4 and T5means for all response variables ($P> 0.05$); and they all were greaterthan T0, T1, T2 and T3.The number of tillers, number of panicles per tiller and rice yield (i.e. 1,000-grain weight and grain yield) in T2 and T3 were greater than ones in T0 and T1 ($P< 0.05$). In addition, the number of tillers, number of panicles per tiller, 1,000-grain weight and grain yield in T1 were significantly greater than ones in T0 ($P< 0.05$), whereas the plant height, panicle length and number of grains per panicle were not significantly different between these treatments ($P> 0.05$).

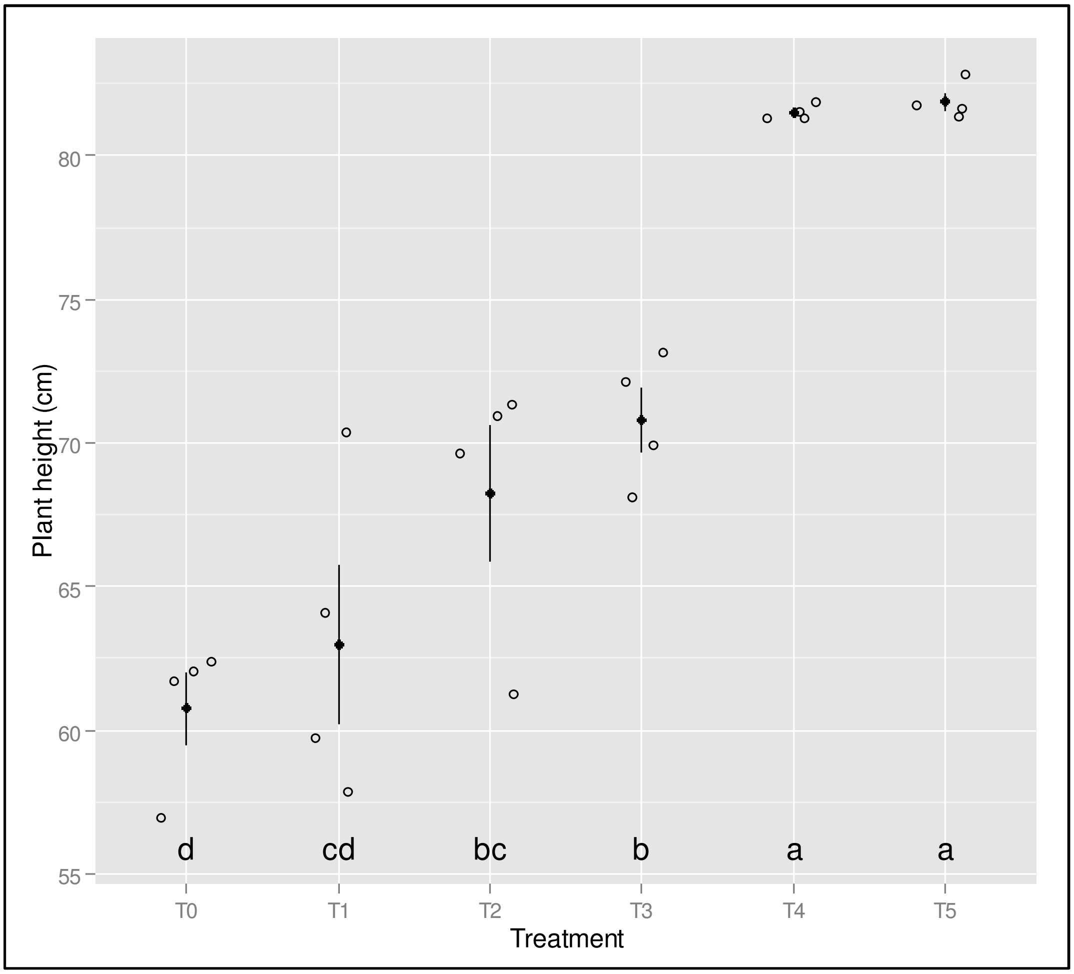

Figure 1: Strip-chart shows the effects of foliar- and soil-applied fertilizers on plant height. Open dots are the data points (n = 4), and close dots are mean values with the bars present standard error. Different letters (a, b, c, d) on the figure indicate a significantly difference (P< 0.05) according to the Tukey's HSD test

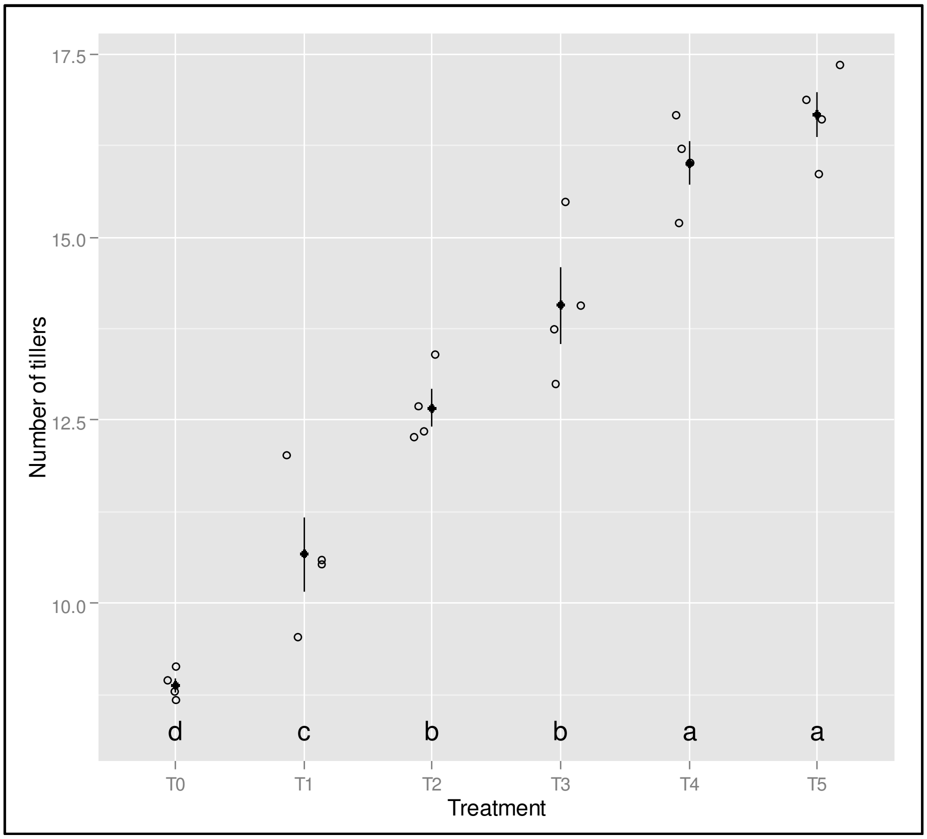

Figure 2: Strip-chart shows the effects of foliar- and soil-applied fertilizers on number of tillers. Open dots are the data points (n = 4), and close dots are mean values with the bars present standard error. Different letters (a, b, c, d) on the figure indicate a significantly difference (P< 0.05) according to the Tukey's HSD test

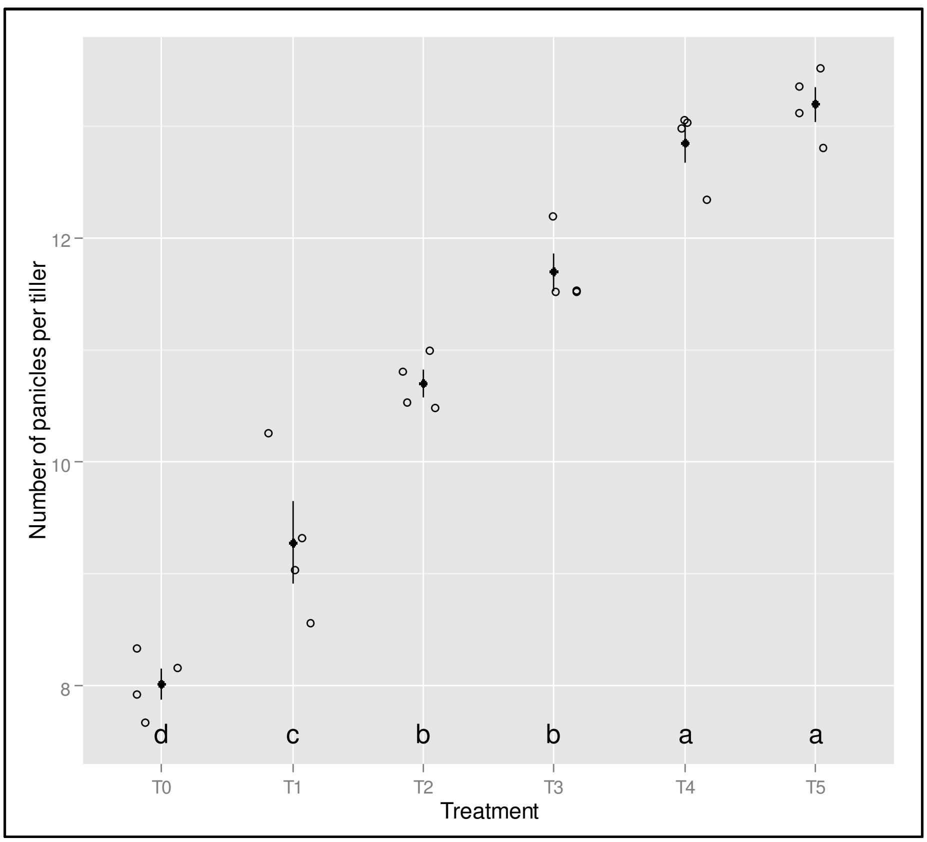

Figure 3: Strip-chart shows the effects of foliar- and soil-applied fertilizers on number of panicles per tillers. Open dots are the data points (n = 4), and close dots are mean values with the bars present standard error. Different letters (a, b, c, d) on the figure indicate a significantly difference (P< 0.05) according to the Tukey's HSD test

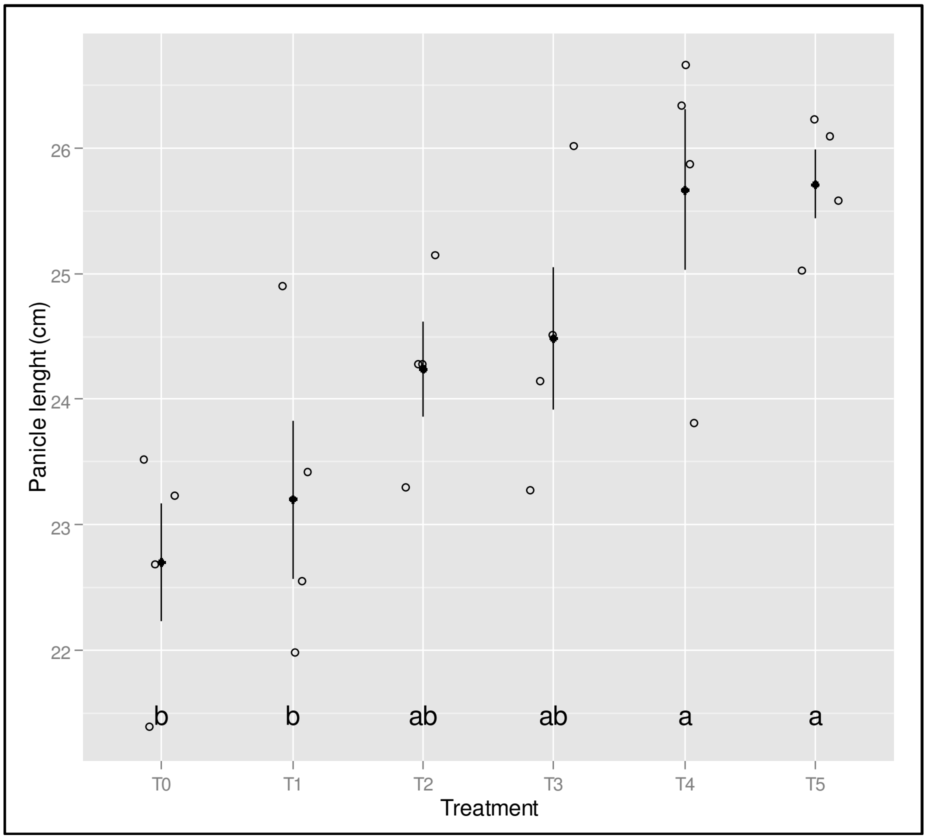

Figure 4: Strip-chart shows the effects of foliar- and soil-applied fertilizers on panicle length. Open dots are the data points (n = 4), and close dots are mean values with the bars present standard error. Different letters (a, b) on the figure indicate a significantly difference (P< 0.05) according to the Tukey's HSD test

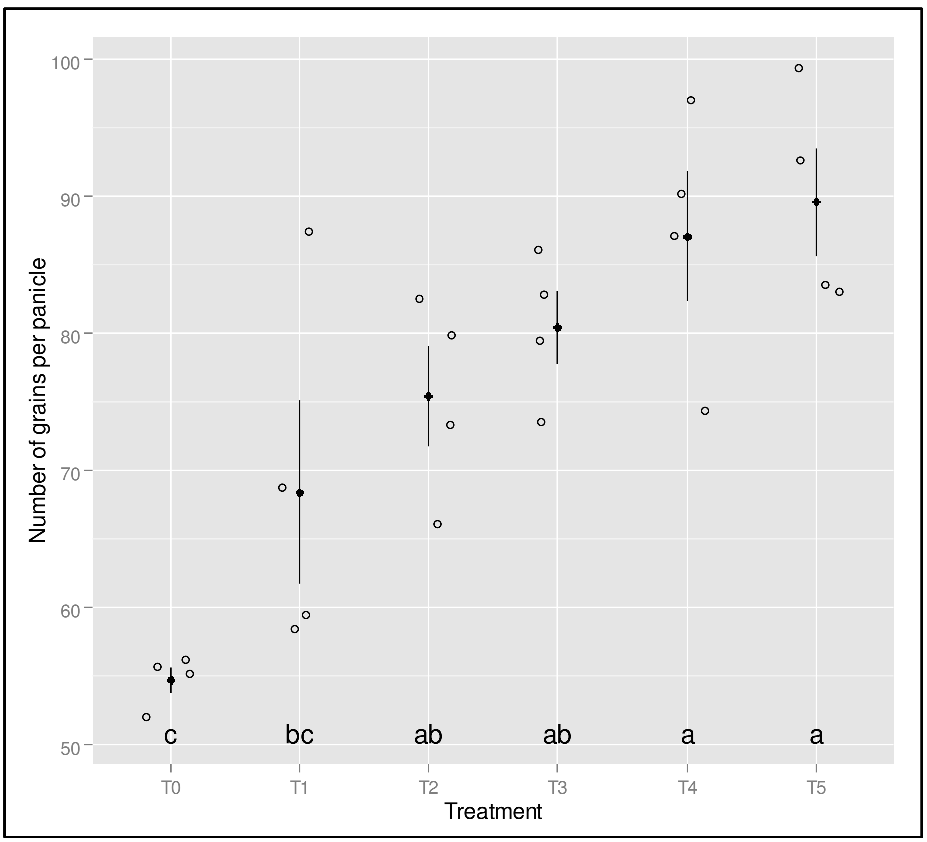

Figure 5: Strip-chart shows the effects of foliar- and soil-applied fertilizers on number of grains per panicle. Open dots are the data points (n = 4), and close dots are mean values with the bars present standard error. Different letters (a, b, c) on the figure indicate a significantly difference (P< 0.05) according to the Tukey's HSD test

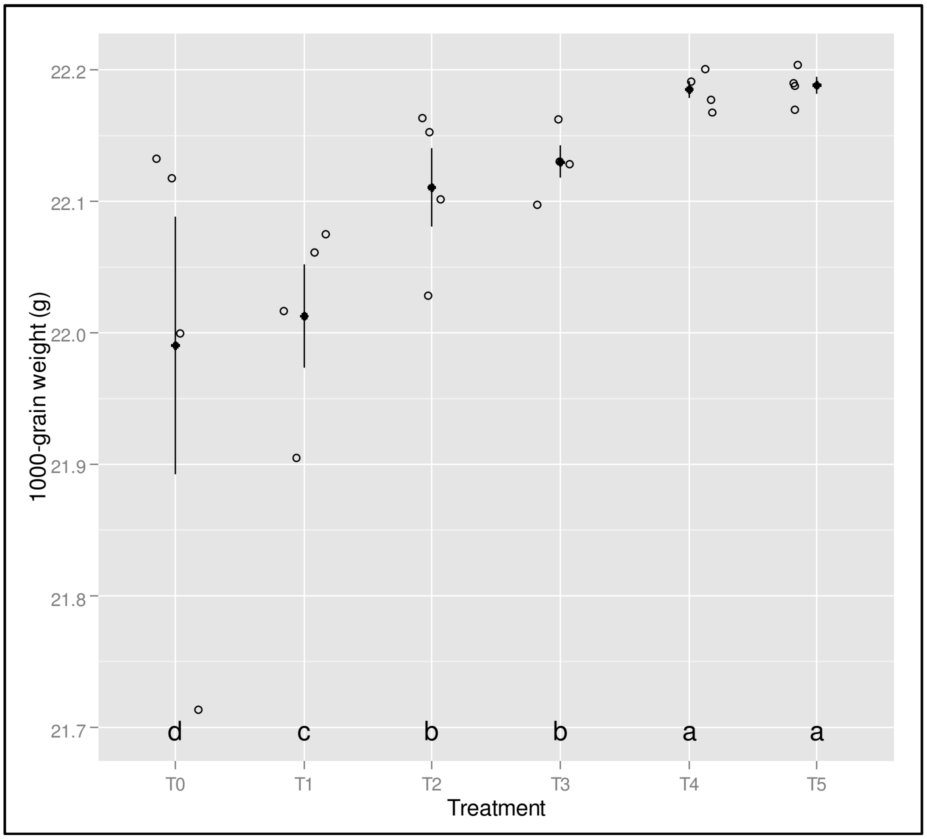

Figure 6: Strip-chart shows the effects of foliar- and soil-applied fertilizers on 1,000-grain weight. Open dots are the data points (n = 4), and close dots are mean values with the bars present standard error. Different letters (a, b, c) on the figure indicate a significantly difference (P< 0.05) according to the Tukey's HSD test

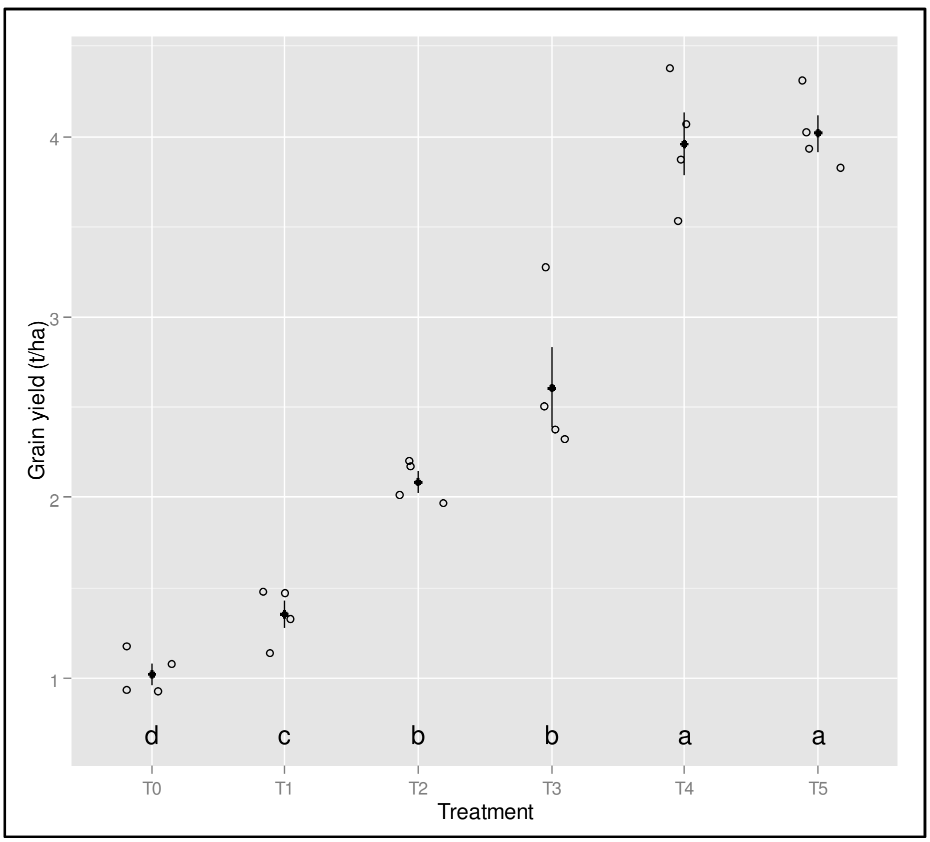

Figure 7: Strip-chart shows the effects of foliar- and soil-applied fertilizers on rice yield. Open dots are the data points (n = 4), and close dots are mean values with the bars present standard error. Different letters (a, b, c, d) on the figure indicate a significantly difference (P< 0.05) according to the Tukey's HSD test

The results of our experiment to evaluate the effects of foliar and soil applied fertilizers on Senpidao rice supported our hypothesis, and demonstrated the positive effects of foliar fertilizer on rice growth, development (i.e. plant height, tiller numbers, panicle numbers per tiller) and rice yield (i.e. grain weight). The response of rice to fertilizer application varies depending on soil type,for example, the greatest yield was found when all nutrients (i.e. N, P, K and S) were applied together for acid clay soil in Cambodia although rice yield increases with increasing amount of fertilizer application (Seng et al., 2001). Although K fertilizer was not recommended for TS soils because of K richness in these heavy textured soils (White et al., 1997), K element may deplete due to long-term use of N and P fertilizers (Seng et al., 2001).Therefore, the positive effects of foliar fertilization may be due not only to N, P,and TEbut also K elements in the foliar fertilizer usedto support rice growth and production. Correcting diagnosis of nutrient deficiency is fundamental for successful foliar fertilization in rice (e.g. Fageria et al., 2009). Rehman et al. (2014) has also demonstrated that improvement in grain yield through foliar application of boron which leadsto increased tiller numbers and grain size but decreased panicle sterility.

4. Conclusions

The findings suggest that improved grain yield (as measured by increased tiller numbers, panicle numbers and decreased panicle sterility) was due to foliar fertilization. Overall, one-fourth ofthe amount of the soil applied fertilizers required could be substituted by foliar fertilization, but it may not substitute up to either half- or total-amount of the recommended rate.

Spraying foliar fertiliser has the additional advanyage of enabling farmers to apply other agrochemical (i.e. herbicides, insecticides or fungicides) in the same operation as tank mixes allowing saving in labor, machinery and energy cost, particularly, when soil applied fertilizers are used less than the recommended rate or immobilzation of nutrients in acidity and alkalinity soil conditions.

5. Acknowledgements

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