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# Study on growth and yield production of bean (*Phaseolus vulgaris*) under alkaline soil condition

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**Abstract**
Common bean (*Phaseolus vulgaris*) growth was evaluated under alkaline soil condition (pH 8.0). 15 varieties at primary growth stage and 4 varieties on sowing to maturity stage tested at Tokyo University of Agriculture (TUA), Tokyo, Japan in 2012, and 2013, respectively. The study was aimed to develop selection method on tolerant varieties of common bean under alkaline soil condition. The leaf area, SPAD value and nutrients uptake at primary growth stage was affected by alkaline soil condition, but the influence was varied by varieties. The identical tolerant varieties at primary growth stage were tested at harvest (maturity stage) which was included control plant. The variety of Jabino was evaluated tolerant variety on alkaline soil condition. The result was suggested that selection of tolerant variety on alkaline soil condition, most of varieties possible to evaluate at primary growth stage.

**Keywords:** study, bean, *Phaseolus vulgaris*, alkaline soil, growth, yield production

## Introduction

Common bean (*Phaseolus vulgaris*) is a major legume crop and important source of protein and calories in many developing countries (FAO 2012). Afghanistan was exported 5502 t of pulses to the world in 2011 (Agriexchange 2013) [1]. Major staple crops and pulses planted area in Afghanistan was 110,043 ha on 2002 **(**FAO 2003). And pulses yield was estimated 1.3 tha$^{-1}$ (ICARDA 2002) [15]. Annual growth productivity of major pulses in Afghanistan indicated higher than the average of world, and it was raised 998 to 1073 kg ha$^{-1}$ during 1991 - 1993 to 2005 – 2007. Legumes are important secondary crops such as common bean, chick pea, grass pea, mung bean, and garden pea and forage legumes in Afghanistan especially in Nangarhar and Bamyan provinces (FAO 1997) [7].

Bamyan is mountainous and agriculturally least productive areas in the country. Most of the land is barren and inaccessible, with water shortages and poor soil quality characterizing. Most fields are snow-fed irrigated by water from the melting snow following winter, or by springs. In general, there is a single crop season and agricultural productivity is limited by difficult terrain, poor soil quality and harsh climatic conditions including severely cold winters, annual spring flooding and propensity to drought in the summer months (UNDP 2015) [26]. The dominant crops cultivate in Bamyan are wheat, barley, legumes and potato. There is little marketing surrounding these crops. The legumes production has been challenging such as dry condition, short period of rainfall, and poor soil condition. Beside of mentioned difficulties the pulses production estimated more than 62.2 t including 47% of common bean in the province (Hussaini 2012) [10]. There are the shortage of good quality seeds and fertilizers with traditional agricultural methods. Also there are few studies and locally researches for scientific indication of the related problems in Bamyan.

The alkaline soil more than pH 8.0 is covered in the Bamyan region, which is caused by high contain of $CaCO_3$ in the soils (Bell 2011). Calcareous soils are extensive and dominate the cropland areas. Soil fertility issues associated with calcareous soils are soluble P by precipitation, poor availability of mineral micronutrients such as Zn, Fe, Mn and Cu and lime is induced B deficiency (Lynch and Clair 2004).

However, there is strong decline in the activity of Jack bean in the pH range of 7-10 (Avinash and Gaikwad 2011) [2]. Highly alkaline soils (pH > 8.0) reduce nitrogen fixation and affect nodulation by reducing the colonization of soil and the legumes rhizosphere by rhizobia

(Bordeleau and Prevost 1994) [3]. Rough seeded lupine (*Lupinus pilosus Murr*.) was more tolerant of high pH than the other Lupinus species. Bitter vetch (*Vicia ervilia* L.) modulated poorly at all levels of solution pH. Addition of bicarbonate decreased shoot growth, nodulation and N concentrations in shoots of most species, early nodulation of Cyprus vetch (*Lathyrus ochrus* L.) DC was not affected by the bicarbonate treatment (Tang and Thomson 1996). Iron-deficiency chlorosis is a common problem when soybean is grown on calcareous soils in the North-Central region of the USA (Goos and Johnson 2000) [9]. In general, at higher pH (> 6) decrease in uptake of micronutrients might be responsible for decreased yield of crop species tested (Fageria and Baligar 2010) [8]. Iron deficiency chlorosis is a common problem for soybean [*Glycine max* (L.) Merr.] on calcareous soil may result in yield loss (Lingenfelser 2005). Iron chlorosis represents a major constraint for the majority of legumes, particularly those intended for the production of seeds (Mahmoudi *et al*., 2005) [19].

The yields of grain legumes are often limited by the lower availability of Fe in the calcareous soils (Karouma *et al*. 2006). The alkali stress and salt concentration have significant interactive effects on alfalfa seeds germination rate (Gao *et al*. 2011). Some legumes are relatively tolerant against such condition. Such mechanisms and physiology of common bean to alkali and drought condition might be useful information to variety selection of common bean variety or landraces under alkaline soil condition. This study aimed to realize the responses and growth of common bean under alkaline soil condition. Selection method established under high pH soil condition of common bean varieties.

## Materials and Methods

### Experiment 1: primary growth of common bean under alkaline soil condition

The experiment carried out in a greenhouse at Tokyo University of Agriculture (TUA), Tokyo, Japan, during 20 May - 25 July 2012, using fifteen varieties of common bean was (Kentucky wonder, Manzunaru, Jabino, Purpu King Oko (Sakata seed Co. Japan), Haibushi Nansei and Naribushi (Futaba Seed Co. Japan), Hatsu Midori, Kurotane Kingugasa, Kentucky 101, Satsukimidori No. 2, Yellow Baron, Purple hope (Taki Sakata seed Co. Japn), and Sama Sekira (Yukijirushi seed Co. Japn). The most of tested varieties were used Japan origin because of the difficulty of collection and import from Afghanistan by deterioration of security.

The primary growth of tested varieties was observed under higher alkaline soil condition with the pH 8.0. The alkaline soil of pH 8.0 (treatment) was adjusted by $Ca(OH)_2$ chemical using namely kanto loam subsoil with pH 6.4 ± 0.3 (control). The Kanto loam soil is distributed to Tokyo, Kanto region, Japan. The 3 kg alkaline soil (pH 8.0) was filed with pot (30 cm diameter and 21 cm height). The ten pots with each variety were used, and another 10 pots with Kanto loam subsoil in each variety was used for control. The N. P. K fertilizer (8: 8: 8) was applied 7 g per pot according to the 200 $kgh^{-1}$ at planting. The water was applied appropriately when soil had dried.

The three seeds were sown in pots on 27 May, and then one moderate plant for experiment was selected after germination. The experiment was laid out by Complete Randomized Design. Plants were supported by stakes 2 cm in diameter and 1.8 m height and whole plants were harvested on 25 and 50 days after planting (here in after 1st and 2nd sampling respectively). The growth measurements were taken as the SPAD value, fresh weight; leaf area, root length and plant height, and then dry weight of leaf, shoot and roots were observed after drying by oven at 80°C by 4 days. The nutrient uptake in the plant of Al, B, Ca, Cu, Fe, K, Mg, Mn, S and Zn was measured as bellow method. The dried leaf stem and root were made with powder and then analyzed using routine analysis method by Inductively Coupled Plasma (ICP) (Shimadzu Co., Japan) and NCH analyzers (Sumigraph NC – 22 F, Sumica Chemical Analysis Service Lst.) (Anderson and Ingram 1993). The dry weight of primary growth was showed by relative values (RV) at 1st and 2nd sampling.

The growth rate of RV (%) was calculated by pH 8.0 (treatment) and control; RV = (treatment / control) x 100; this is an indicator of alkaline tolerance (Chaugool, *et al*. 2013) [5]. RV of primary growth in tested varieties was classified in three groups with > 100%, > 80 - 100% and 80%＜; this RV% showed bigger, moderate and feeble growth under alkaline soil condition.

### Experiment 2: Grain yield and biomass production of common bean under high pH condition

The experiment was conducted in green house same as experiment 1 at TUA during 1 May to 15 Aug 2013. The grain yield and biomass production under alkaline soil condition was observed at maturity (seed harvesting) growth stage. Four common bean varieties was evaluated to alkaline soil by strong (Jabino), moderate (Kentucky Wonder and Oko) and feeble (Hatsu Midori) plant growth in primary stage selected from experiment 1, were obtained from Japan seed bank. The experiment laid out in RCBD with 3 replications of four varieties in two pH levels. The soil pH adjusted to 8.0 for alkaline soil condition and control as like experiment 1. The 11 kg alkaline soil was filed with pots (30 cm diameter and 35 cm height). The five pots with each variety were used, and another five pots with Kanto loam subsoil in each variety was used for control. The seeds sown, selection of the tested plant and cultivation method had done as like experiment 1, and whole plants were harvested on 15 August. The maturity growth stage was measured in root, stem, leaf and pods, pod yield, number of pod per plant, 100 grain weight and number of seed per plant and dry matter. The dried leaf, stem, and root were made with powder and then analyzed using routine analysis method by ICP and NCH analyzer as like experiment 1 on nutrients uptake by the plants, under alkalinity. The outputted data from ICP and NCH analyzers as ppm, transformed to g $kg^{-1}$ concentration in dry matters, the absorption of nutrients elements compared the treatments with control.

For assessing on biomass production and yield components (such as seed weight, No of Pod and seed) at maturity stage in 105 days after planting (DAP), the data statically compared between 2 pH and 4 varieties using t-test, LSD and Tukey HSD tests by SPSS.

## Result and Discussion

### Experiment 1: primary growth of common bean under alkaline soil condition

The classification of tested varieties based on growth relative values (RV) by dry weight of 1st and 2nd sampling was shown in Table 1. At 1st sampling, the RV > 100% (bigger growth), > 80 - 100% (moderate growth) and 80%＜ (feeble growth) were included 6, 4 and 5 varieties respectively. Bigger growth was Jabino, Purple Hope, Haibushi Nansei, Kentucky wonder, Kurotane Kingugasa and Oko variety. Moderate growth was Puropu King, Sama Sekira, Yellow Baron and Manzunaru variety. Feeble growth was Kentucky 101, Naribushi, Nerina, Satsukimi dori No. 2 and Hatsu Midori variety. The different results compared to 1st sampling was observed in the 2nd sampling. The bigger, Moderate and feeble growth were included 4, 7 and 4 varieties at 2nd sampling, respectively. The bigger RV varieties were thought suitable to alkaline soil condition. The bigger- RV shown in 1st and 2nd sampling was Jabino and Haibushi Nansei variety. Those Varieties might be adapting to alkaline soil condition. The RV 80%< showed varieties of Naribushi and Hatsu midori variety was thought weak to alkaline soil condition because of low growth RV.

Correlation in RV of dry weight of plant and plant height, root length and leaf area at 1st sampling is shown in fig. 1. The Plant height, root length and leaf area was shown positive correlation with RV. Correlation in RV of dry weight of plant and plant height, root length and leaf area at the 2nd sampling is shown in Fig. 2. The positive correlation between RV and growth parameter was shown in leaf area but not in root length and plant height had small correlation. The results suggested that leaf area might be an indicator of variety selection for alkaline soil condition.

At the 1st sampling the nutrients content (mg 100 $g^{-1}$) in the plant organs focused on Ca, K and Mg is shown in table 2 and classified on nutrients uptake relative values (RV) shown as RV > 100% (bigger growth), > 80- 100% (moderate growth) and 80% < (feeble growth). On the plant roots the element of Ca concentered as bigger growth, Mg as moderate growth and K as feeble growth. On the plant stem the Mg concentrated as bigger growth, and Ca and K moderate growth. Furthermore, on the plant leaf the elements of Ca and Mg concentrated as bigger growth K as moderate growth (Table 2). Also at the 2nd sampling on the plant roots the elements of Mg and Ca concentered as bigger growth, and, K as moderate growth. On the plant stem the element of Mg concentrated as bigger growth, Ca and K as moderate growth. Also on the plant leaf the elements.

**Experiment 2: Grain yield and biomass production of common bean under high pH condition**

The result of this experiment on comparison of biomass production and yield components between 4 varieties the LSD and Tukey tests, displayed the significantly different on total dry matter, number of seed per pod (SPPD) and 100 seed weight (HSW) of the plants. Kentucky wonder and Jabino produced the highest dry matter of 15.45 g $p^{-1}$ and 13.47 g $p^{-1}$ respectively in alkaline treatment, which is significantly different from other varieties. In addition, Jabino made highest 100 seed weight (29.6 gr) significantly different from other varieties, afterward the Oko produced (21.8 gr) of 100 seed weight. It means that Jabino resisted with alkaline soil condition than other varieties (Table 3 A, B).

Seeing on elements uptake on the plants parts at maturity stage assessed as procedure of 1st experiment. Considering on nutrients uptake by the plants seeds, treatments compared with control, shown significantly difference on concentration of Fe, K, and P (Table 4).

Using t test the means of treatments matched with control, exposed significant difference just on concentration of Ca, but other elements not differed meaningfully (Table 5).

Entirely at this study different response of 15 common bean varieties to alkali stress observed. Uptake of micronutrients significantly decreased at primary growth stages and relatively at maturity stage of the plants. Similar reported by Algeria (1998), availability of Fe, Zn, Mn, Cu, B and P were poor at early growth stage. As reported USDA (1998) [27] at maturity stage Mn, Cu, Zn and B were inadequate on the leaf. Same as report of Hopkins (2005) [14] availability of P was poor in primary growth stages, but differed at maturity stage in this study. Such as report of Slatni (2007); Zaiter (1992) [29], in this study too Fe deficiency varied among verities, likewise seed yield variances amongst bean varieties under pH 8.0. Also some varieties were sensitive to alkali stress at pH 8.0, Similar with report of Goenaga (2013) [12]. The more significant finding from this study was variation on dry matter production and uptake of micronutrients in primary growth stage. Alkaline stress of common bean varied between different growth stages. This study implied that tolerance of common bean at different growth stages varied between varieties as well. Different response of varieties at different growth stages indicated that screening at one stage does not guarantee the selection of a variety tolerant to all stages. Also the result of this study displayed that pH 8.0 affected the elements uptake, 100 seed weight and dry matter production of common bean and suggested that selection of tolerant variety on alkaline soil condition, most of varieties possible to evaluate at primary growth stage. Between the varieties Jabino could be identified the pH 8.0 resistance variety in this study. It might be use as a chick variety in similar alkaline studies. Since this study conducted under climate of Tokyo in the green house, so further research recommended under the natural alkaline soil condition in the field.

**Table 1:** Classification of tested varieties based on growth relative values (RV) by dry weight of 1st and 2nd sampling.

| Sampling | Range of RV | Varieties |
|---|---|---|
| 1st | > 100% | Jabino, Purple Hope, Haibushi Nansei, Kentucky wonder, Kurotane kingugasa, OKo |
| | 80 - 100% | Puropu King, Sama Sekira, Yellow Baron, Manzunaru |
| | 80%< | Kentucky 101, Naribushi, Nerina, Satsukimi dori No. 2, Hatsu Midori |
| 2nd | > 100% | Jabino, Puropu King, Haibushi Nansei, Yellow Baron, |
| | 80 - 100% | Kentucky 101, Nerina, Satsukimidori No. 2, Oko, Purple Hope Manzunaru, Kuretane kingugasa |
| | 80%< | Kentucky wonder, Naribushi, Hatsu midori, Sama Sekira |

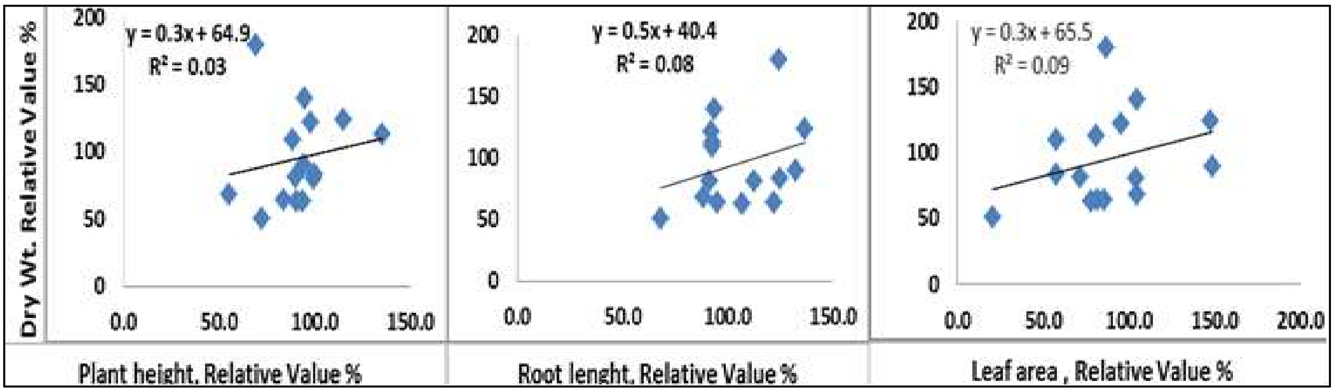


**Fig 1:** Correlation in RV of dry weight of plant and plant height, root length and leaf area at the 1st sampling.

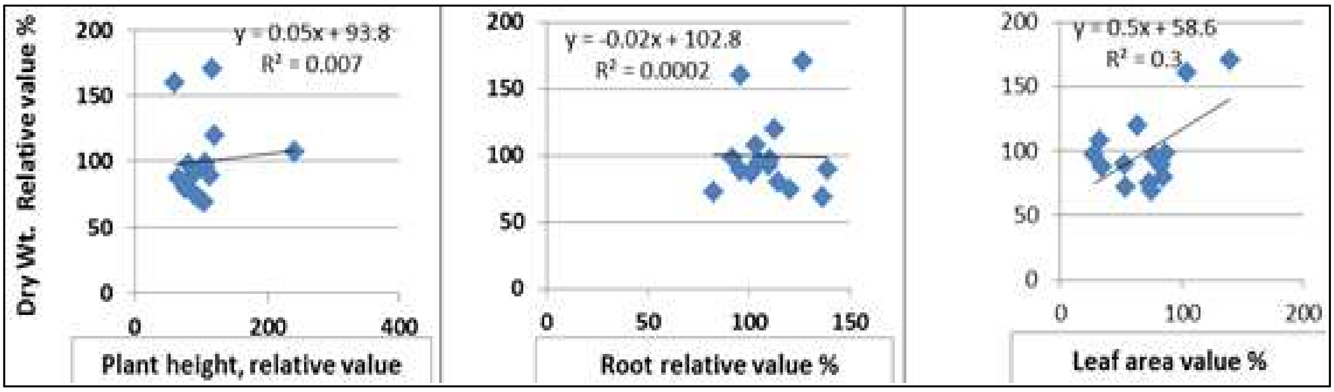


**Fig 2:** Correlation in RV of dry weight of plant and plant height, root length and leaf area at the 2nd sampling.

**Table 2:** Classification of some elements concentration on the plant organs based on uptake relative values (RV) of 1st and 2nd sampling.

| Elements ( mg 100 g$^{-1}$) | | | | |
|---|---|---|---|---|
| **Sampling** | **RV% (pH 8 / 6 *100)** | **Root** | **Stem** | **Leaf** |
| 1 | >100% | Ca (181.82) | Mg (158.70) | Ca (111.29), Mg (164.29) |
| | 80-100% | Mg (100.0) | Ca (86.17) K (91.88) | Cu (100.0), K (83.62) |
| | 80% < | K (78.79) | - | - |
| 2 | >100% | Ca (150.67), Mg (176.04) | Mg (154.69) | K (125.13), Mg (144.62) |
| | 80-100% | K (90.48) | Ca (91.30) K (96.73) | Ca (99.64) |
| | 80% < | - | - | - |

>100% indicates element uptake not effected, 80-100% indicates moderate effected and 80% < indicates more effected by pH 8 on the plants organs.

**Table 3:** (A, B) Mean comparison for 4 common bean varieties evaluated under pH-stressed condition on biomass and yield production at 105 DAP

| **A** | **Control (pH 6.0)** | | | | | **Treatment (pH 8.0)** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variety | Leaf | Stem | Root | Whole | Yield(g p$^{-1}$) | Leaf | Stem | Root | Whole | Yield (g p$^{-1}$) |
| KW | 9.01 | 8.66 | 5.97 | 23.64 | 6.09 | 5.41$^{a}$ | 4.83$^{a}$ | 5.18$^{a}$ | 15.45$^{a}$ | 1.05$^{a}$ |
| Ja | 5.91 | 11.36 | 6.65 | 23.93 | 3.16 | 4.03$^{ab}$ | 5.01$^{ab}$ | 4.43$^{ab}$ | 13.47$^{ab}$ | 1.76$^{ab}$ |
| Ok | 5.69 | 5.06 | 4.23 | 14.98 | 4.66 | 2.27$^{bc}$ | 1.71$^{cd}$ | 1.89$^{cd}$ | 5.87$^{cd}$ | 2.76$^{abd}$ |
| HM | 2.56 | 2.49 | 1.29 | 6.35 | 2.33 | 1.30$^{cd}$ | 1.29$^{d}$ | 0.79$^{d}$ | 3.38$^{d}$ | 1.90$^{abcd}$ |

a, b, c, d: Different letters means difference is significant at the .05 level, used LSD and Tukey HSD tests.
Whole = dry weight of leaf, stem and root, Yield = grain yield.
Kentucky wonder produced the highest dry matter with 15.45 g p$^{-1}$, followed by Jabino with 13.47 g p$^{-1}$ in alkaline treatment, significantly different from two other varieties.

| **B** | **Control (pH 6.0)** | | | | **Treatment (pH 8.0)** | | | |
|---|---|---|---|---|---|---|---|---|
| Variety | HSW | NoPP | SPPD | SPPT | HSW | NoPP | SPPD | SPPT |
| KW | 26.1 | 5.2 | 4.4 | 23.7 | 10.7$^{a}$ | 2.3$^{a}$ | 2.2$^{a}$ | 6.5$^{a}$ |
| Ja | 29.2 | 3.7 | 2.4 | 9.6 | 29.6$^{b}$ | 2.1$^{ab}$ | 2.0$^{ab}$ | 5.1$^{ab}$ |
| Ok | 28.9 | 4.4 | 3.4 | 16.1 | 21.8$^{c}$ | 2.9$^{abc}$ | 3.9$^{c}$ | 12$^{abc}$ |
| HM | 19 | 3.2 | 3.8 | 11.7 | 12.7$^{ad}$ | 3.3$^{abcd}$ | 2.7$^{abd}$ | 11.3$^{abcd}$ |

a, b, c, d: Different letters means difference is significant at the .05 level, used LSD and Tukey HSD tests.
Whole = dry weight of leaf, stem and root, Yield = grain yield, HSW = 100 seed weight, NoPP = Number of Pod per plant, SPPD = Number of Seed per Pod, Number of Seed per plant. Jabino made highest 100 seed weight (29.6 gr) significantly different from other varieties, afterward that Oko produced (21.8 gr) of 100 seed weight.

**Table 4:** The means comparison of macronutrients and micronutrients contented on the plant seed

| Macronutrients | | | | | Micronutrient | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Seed** | **PH** | **Mean (g $kg^{-1}$)** | **SE** | **DF** | **Seed** | **PH** | **Mean (g $kg^{-1}$)** | **SE** | **DF** |
| N | 6.0 | 46.2 ns | 0.90 | 3 | B | 6.0 | 0.002 ns | 0.01 | 3 |
| | 8.0 | 45.6 ns | 2.31 | 3 | | 8.0 | 0.004 ns | 0.02 | 3 |
| Al | 6.0 | 1.04 ns | 0.2 | 3 | Cu | 6.0 | 0.05 ns | 0.01 | 3 |
| | 8.0 | 1.2 ns | 0.2 | 3 | | 8.0 | 0.07 ns | 0.01 | 3 |
| Ca | 6.0 | 11.5 ns | 2.2 | 3 | Fe | 6.0 | 0.5 * | 0.1 | 3 |
| | 8.0 | 12.8 ns | 2.9 | 3 | | 8.0 | 0.8 * | 0.1 | 3 |
| K | 6.0 | 107.9 * | 1.6 | 3 | Mn | 6.0 | 0.1 ns | 0.02 | 3 |
| | 8.0 | 125.5 * | 3.8 | 3 | | 8.0 | 0.08 ns | 0.01 | 3 |
| Mg | 6.0 | 11.5 ns | 0.9 | 3 | Zn | 6.0 | 0.2 ns | 0.02 | 3 |
| | 8.0 | 11.9 ns | 1.2 | 3 | | 8.0 | 0.2 ns | 0.03 | 3 |
| P | 6.0 | 67.5 * | 1.5 | 3 | | | | | |
| | 8.0 | 85.6 * | 3.9 | 3 | | | | | |

* indicates significant different at the 5% level, according to a t – test

**Table 5:** The means of nutrients uptake on the plant leaf

| Macronutrients | | | | | Micronutrient | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Leaf** | **pH** | **Mean (g $kg^{-1}$)** | **SE** | **DF** | **Leaf** | **pH** | **Mean (g $kg^{-1}$)** | **SE** | **DF** |
| N | 6.0 | 33.4 ns | 1.4 | 3 | B | 6.0 | 0.7 ns | 0.1 | 3 |
| | 8.0 | 31.5 ns | 2.3 | 3 | | 8.0 | 0.6 ns | 0.1 | 3 |
| Al | 6.0 | 217.8 ns | 52.0 | 3 | Cu | 6.0 | 0.2 ns | 0.02 | 3 |
| | 8.0 | 254.2 ns | 7.8 | 3 | | 8.0 | 0.1 ns | 0.01 | 3 |
| Ca | 6.0 | 374.6 * | 19.4 | 3 | Fe | 6.0 | 25.4 ns | 4.0 | 3 |
| | 8.0 | 479.6 * | 13.0 | 3 | | 8.0 | 24.0 ns | 0.6 | 3 |
| K | 6.0 | 220.7 ns | 18.0 | 3 | Mn | 6.0 | 1.3 ns | 0.2 | 3 |
| | 8.0 | 215.5 ns | 9.9 | 3 | | 8.0 | 1.09 ns | 0.03 | 3 |
| Mg | 6.0 | 63.06 ns | 5.0 | 3 | Zn | 6.0 | 0.6 ns | 0.2 | 3 |
| | 8.0 | 53.07 ns | 4.9 | 3 | | 8.0 | 0.4 ns | 0.03 | 3 |
| P | 6.0 | 40.1 ns | 2.8 | 3 | | | | | |
| | 8.0 | 42.9 ns | 1.9 | 3 | | | | | |

*: indicates Significant at%1 level, ns: no significant.

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