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THESIS

EFFECTS OF ARBUSCULAR MYCORRHIZAL FUNGI COLONIZATION ON PHOSPHORUS UPTAKE AND GROWTH OF BABY CORN ON A SANDY SOIL

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A field experiment was conducted at the Royal Development Study Center in Khao Hin Son from September to November, 2007 to examine the efficiency of AM fungi, *Glomus* species, in promoting growth of baby corn (*Zea mays* L.) on a sandy soil, Chan Thuek series (Cu) at four rates of P fertilizer and two croppings, Crop 1 and Crop 2 were running parallelly at the same period. The experimental design was 4 x 2 factorial treatment combinations with 4 replications in a randomized complete block design. One factor is rates of P fertilizer application, T_1, T_2 T_3 and T_4, which contains 0, 60, 120 and 240 kg P_2O_5 ha^{-1} respectively. The other is arbuscular mycorrhizal fungal inoculation. I_1 was not inoculated and I_2 was inoculated with *Glomus*. Two factor analyses of variance (ANOVA) and Duncan multiple range test were used to partition the variance into the main effects and the interaction between mycorrhizal colonization and phosphorus fertilizers.

As to fertilization rate, neither Crop 1 nor Crop 2 had a significant impact from the measured soil properties. For Crop 1, inoculation had a highly significant ($p<0.01$) effect on shoot height and fresh weight. And it also had a significant ($p<0.05$) effect on dry weight. Fertilizer rate had a highly significant ($p<0.01$) effect on shoot height, fresh weight and dry weight. On the other hand, there was no significant interaction between AM inoculation and P fertilizer rate. For Crop 2, fertilizer rate had highly significant ($p<0.01$) effect on shoot height and it also had a significant ($p<0.05$) effect on shoot fresh weight, but there was no significant interaction between AM inoculation and P fertilizer rate. For both Crop 1 and Crop 2, there was no significant ($p>0.05$) interaction between phosphorus fertilizer and AM fungi inoculation on nutrient (nitrogen, phosphorus and potassium) uptake.

For further study, comparing native and inoculated AM fungi should be tested under field experiment. And T_2, T_3 and T_4 rate should be changed from 60, 120 and 240 kg P_2O_5 ha^{-1} to 30, 60 and 90 kg P_2O_5 ha^{-1} respectively to examine the effect of P fertilizer under lower fertility status.

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Student's signature | Thesis Advisor's signature

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INTRODUCTION

The heavy use of chemical inputs including fertilizers and pesticides has resulted in pollution, decreased biodiversity in intensively-farmed regions, and environmental degradation linked to the use of chemical inputs is increasingly widespread and sometimes irreversible. Beneficial microorganisms, including soil-borne symbionts, N_2-fixing bacteria and arbuscular mycorrhizal (AM) fungi, provide minerals to plants and are directly implicated in crop production (Plenchette *et al*., 2005).

Though plants require adequate phosphorus (P) from the very early stages of growth for optimum crop production (Grant *et al*., 2001), excess P supply in the soil is a major environmental concern (Plenchette *et al*., 2005). Moreover the reserves of P in the world are finite and are gradually being depleted (Tiessen, 1995). Thus there is a need to develop agricultural systems based on meeting minimum P requirements for crops.

Many soils in the tropics are fragile and prone to degradation. Some characteristics of tropical soils put severe constrains on food production. Sanchez *et al*. (2003) proposed a fertility capability soil classification that identifies the major attributes that constrain plant production. These constrains include soil moisture stress, low nutrient capital, erosion risks, low pH with aluminum (Al) toxicity, high phosphorus (P) fixation, low levels of soil organic matter, and a loss of soil biodiversity (Irene and Thomas 2006).

Encouragement of AM associations may enhance P uptake by crops early in the growing stage, improving crop yield potential and replacing excessive fertilizer P applications. Use of effective P management practices, whether through efficient fertilizer use or encouragement of mycorrhizal associations can optimize the economics of crop production while avoiding negative effects of P on environmental quality (Grant *et al*., 2005).

For better nutrient management in the tropics, an increased use of biological potential is important (Irene and Thomas 2006). Keys to agricultural success in the tropics are to use adequate plant species diversity and to use perennial plants to maintain soil fertility, to guard against erosion and to fully utilize resources (Altieri, 2004).

Maize is an important crop in Thailand with over 4.5million tones being harvested from 1.2 million hectares in the year 2002/3 (Benchaphun *et al*., 2004). Its production is mostly for the domestic feed industry. Eighty percent of the total land area in Thailand has low fertility soils (Miller, 2000; Subramanian, 1997). Hence, inorganic and organic fertilizers are essential in order to improve crop production, and typically fertilizer containing 5-20 kilograms of P per hectare is recommended for maize planting (Nidchaporn, 2005; Miller, 2000).

As many reports have proved that AM fungi inoculation is effective to increase crop yield under sterilized soil (Tawaraya *et al*., 1995; Sato *et al*., 1998; Nidchaporn, 2005), the efficiency of these AM fungi should be tested in the field where native AM fungi coexist. When the native AM fungi are effective enough, soil and fertilizer management would be more effective technology than AM fungi inoculum.

Baby corn grows well in a wide range of soil types but it thrives best in loose, well drained soil. A suitable soil for baby corn has a wide pH range, from 5.5 to 7.0. It can also grow in very acid soils, but cannot grow in wetlands with low drainage. And the plant needs full sunlight for its growth (Land Development Department, 2006).

In order to increase the effective use of applied fertilizer, the native AM fungi which can colonize in baby corn roots and promote crop yield should be encouraged (Miller, 2000).

OBJECTIVES

1. To examine the effect of AM fungi inoculation at different levels of soil fertility on baby corn (*Zea mays* L.) growth and to increase the yield by inoculum in low fertility sandy soils.

2. To improve P nutrition of baby corn by enhancing mycorrhizal associations and improving P fertilizer use efficiency for suitable crop production.

LITERATURE REVIEW

1. Phosphorus (P) Supply to Crops

In soils cultivated for decades, about 75 percent of the total P is in inorganic forms, more than 20 percent is organic P and a few percent is in soil microbial biomass (Grant *et al.*, 2002). The inorganic P in the soil solution is present as orthophosphate ions, usually $H_2PO_4^-$ or HPO_4^{2-} depending on soil pH (Jaillard *et al.*, 2001). Replenishment of the ions in soil solution relies on mobilization of P in soil by physico-chemical and biological mechanisms (Hinsinger, 1998).

Low P availability limits plant growth in many acid soils of the Tropics. Phosphorus deficiency is mainly caused by strong adsorption of $H_2PO_4^-$ to aluminum (Al) and iron (Fe) oxides, turning large proportions of total P into forms that are unavailable to plants. Phosphorus in soils is present in pools varying in availability, and pools with the lowest availability are the largest in Oxisols (Irene and Thomas, 2006).

Plant species may differ in their external requirements for P because of the differences in their maximum growth rate, in their ability to take up phosphate, or in the utilization of phosphate within the plant (Barrow, 1977). The only direct effect of AM fungi on plant growth is probably through nutrient uptake (Powell and Bagyaraj, 1984).

Phosphorus management practices must be designed to address the nutrient requirements of the individual crops and the nutrient management goals for the crop production systems (Grant *et al.*, 2005).

The depletion of the P ions concentration of the solution at the root surface by absorption controls the release of P ions at the soil-solution interface by diffusion and their transport by diffusion in solution. The release of P ions from soil solid phase to solution varies with time and the gradient of P ion concentration and it can be quantified by sorption-desorption and isotopic dilution methods, which give the same results if both variables are taken into account (Schneider and Morel, 2000).

The rate of P uptake is related to the rate of water uptake and P concentration in soil solution. The P ions near the root hairs are absorbed quickly, resulting in a depletion zone with a decreasing P concentration gradient near the root surface (Bagshaw *et al*., 1972).

The importance of adequate tissue P concentrations during early-season growth has been reported in many different crops species (Grant *et al*., 2001). Enhanced early-season P nutrition in corn can increase the dry matter partitioning to the grain at later development stages (Gavito and Miller, 1998; Mollier and Pellerin, 1999).

A specific role for AM fungi in the uptake of rock phosphate has sometimes been discussed (Irene and Thomas, 2006), because mycorrhizal plants are thought to be more effective in utilizing rock phosphate than non mycorrhizal plants. But the mechanisms involved have received little attention. Ness and Vlek (2000) noted that only mycorrhizal maize took up P from hydroxyl-apatite, and that the P was subsequently transferred to maize.

Adding easily soluble P fertilizers or rock phosphate might have different feedback on mycorrhizal functioning. Addition of triple superphosphate often reduces mycorrhizal functioning except under conditions of very severe P limitation, as reported for an annual crop on a poor sandy soil (Bagayoko *et al*., 2000) or coffee (*Coffea arabica* L.) on P fixing soils (Siqueira *et al*., 1998). In contrast, addition of insoluble P sources such as rock phosphate can even increase mycorrhizal colonization (Vanlauwe et al., 2000; Alloush and Clark, 2001).

The main strategy to cope with P deficiency in the Tropics has been the addition of fertilizers, either in the form of synthetic fertilizer or in the form of rock phosphate (Sanchez, 2002), but the use of synthetic fertilizer is relatively inefficient because of P fixation. Most of the fertilizer phosphate in P fixing soils ends up in fixed pools, having a recovery of only approximately 10-20 percent (Irene and Thomas, 2006).

Even though P is the element that usually limits crop production in the humid Tropics, the amount of total inorganic P in tropical soils may not be low (Cardoso *et al*., 2006). The use of deep-rooting trees and shrubs that can take up P from the subsoil (Makumba, 2006) and of plants that can mobilize insoluble inorganic P sources can be a sustainable strategy, because the depletion due to mining the pools is not likely to become problematic in the short term.

2. Arbuscular Mycorrhizal (AM) Fungi

2.1 Nature of Arbuscular Mycorrhizal Fungi

Arbuscular mycorrhizal (AM) fungi are one of the few plant-fungus associations with fossil record and may even have facilitated the origin of land flora (Morton and Benny, 1990). The estimated origin of arbuscular-like fungi is 353-462 million years ago, which is consistent with the hypothesis that these fungi were instrumental in the colonization of land by ancient plants (Simon *et al*., 1993).

The fungi that are probably most abundant in agricultural soils are AM fungi. They account for 5-50 percent of the biomass of soil microbes (Olsson *et al*., 1999). Biomass of hyphae of AM fungi may amount to 54-900 kilograms per hectare (Zhu and Miller, 2003), and some products formed by them may account for another 3,000 kilograms (Lovelock *et al*., 2004). The external mycelium attains as much as 3 percent of root weight (Jakobsen and Rosendahl, 1990).

AM fungi have coexisted and coevolved with plants for about 400 million years (Malloch *et al*., 1980; Pirozynski and Dalpé, 1989).This means that most of the root systems of agricultural crops are colonized by AM fungi (Harley and Harley, 1987; Sieverding, 1991).

The ability of AM fungi to enhance host plant uptake of relatively immobile nutrients, in particular P, and several micronutrients, has been the most recognized beneficial effect of mycorrhiza. Rhizospere interaction occurs between AM fungi and other soil microorganisms with effects on plant nutrient balances, such as nitrogen-fixing bacteria and plant growth promoting rhizobacteria (Paula *et al*., 1993).

AM colonization may furthermore protect plants against pathogens. AM fungi interact with heavy metals/micronutirents. They can restore the equilibrium of nutrient uptake that is misbalanced by heavy metals (Carneiro *et al*., 2001; Siqueira *et al*., 1999).

AM fungi are ubiquitous in soils throughout the world. They form mycorrhizae with a majority of plant species and show little host specificity (Powell and Bagyaraj, 1984). It is well known that mycorrhizal fungi can improve P uptake and plant growth, and it results from a symbiosis between fungus and its host plants that exclude non-mycorrhizal species of *Chenopodiaceae* and *Cruciferaceae* (Nieves *et al*., 2005; Tawaraya *et al*., 1995; Suzuki *et al*.1999).

A substantial number of crops are strongly depended on arbuscular mycorrhizae. Norman *et al*. (1995) showed only a few families and genera of plants that do not generally form arbuscular mycorrhizae; these include; *Brassicaceae*, *Caryophyllaceae*, *Cyperaceae*, *Juncaceae*, *Chenopodiaceae*, and *Amaranthaceae*.

Under natural conditions there is a harmonious combination of fungal microflora with the roots they occupy. Mycorrhizae occur in about 83 percent of dicotyledonous and 79 percent of monocotyledonous plants thus far investigated (Trappe, 1987). Almost all tropical crops are mycorrhizal and many of them strongly respond to arbuscular mycorrhizae (Irene and Thomas, 2006).

2.2 Identification of Arbuscular Mycorrhizal Fungi

The most widely used classification recognizes five board mycorrhizal groups. They are based solely on the position of fungal mycelium in relation to root structure; the categories are purely descriptive and imply no functional significance. Although these subdivisions may serve useful purposes in promoting mycorrhizal research, their significance is not completely understood. They are as follows (Ajit, 1998);

ECTO-ectrophic; ectcellular; sheathing; hartigian
ENDO-endotrophic; phycomycetous; vesicular-arbuscular; arbuscular
ENDO-endotrophic; ericaceous; ericoid
ECTENDO-ect-endotrophic;ericaceous;arbutoid
ENDO-endotrophic; orchidaceous

The identification of AM fungi are based largely on the structure of their soil-borne resting spores. The spore features used to identify AM fungi are spore development, spore arrangement, spore shape, spore size, spore ornamentation, spore wall layers, spore staining reactions and spore germination (Morton, 1988; Brundrett *et al.*,1996).

Taxonomy and identification of AM fungi are almost exclusively based on the distinct morphology of their spores and it is very difficult to distinguish between genera or species when fungi are within root tissues (Ajit, 1998).

AM fungi produce glomalin, a specific soil-protein, that its biochemical nature is still unknown. Glomalin is quantified by measuring several glomalin-related soil-protein pools (Rillig, 2004). Glomalin has a longer resistance time in soil than hyphae, allowing for a long persistent contribution to soil aggregate stabilization. The residence time for hyphae is considered to vary from days to month (Langley and Hungate, 2003; Staddon *et al.*, 2003) and for glomarin from 6 to 42 years (Rillig *et al.*, 2001).

Glomalin is considered to stably glue hyphae to soil (Wright and Upadhyaya, 1998). The mechanism is the formation of an appressorium near hyphae (Jastrow and Miller, 1997; Rillig et al., 2002), which leads to stability of aggregates. Glomalin is present in soil in large amounts (Lovelock *et al.*, 2004; Rillig *et al.*, 2001). Moreover, glomalin production increases carbon flow to soil, therefore soil aggregation rates are expected to increase. The concentration of glomalin was correlated with stabilization of soil aggregates after a 3 years transition of a maize cropping system (Wright *et al.*, 1999).

There are indications that some crop rotations favor glomalin production and aggregate stabilization more than others (Wright and Anderson, 2000). Thus, management of cropping systems to enhance soil stability and reduce erosion may often benefit from consideration of the factors which control crop production yield and maintain external hyphae and glomalin (Irene and Thomas 2006).

3. Mycorrhizal Inoculation

3.1 Impact of Soil P Levels on Mycorrhizal Association

The role of AM fungi in mineral nutrition has been discussed several times recently (Smith, 1980; Bowen and Smith, 1981). It is now well established that mycorrhizae can improve the P nutrition of a host, particularly in low fertility soils, and it is likely that they can also assist in the uptake of other ions such as copper (Cu) and zinc (Zn) (Powell and Bagyaraj, 1984).

The uptake of phosphate by plants from soil will usually be limited by the rate of movement of the phosphate to the plant root rather than by the rate of absorption at the root surface (Nye, 1977). In soils with high capacities to absorb phosphate, such as Andosols, phosphate concentrations in soil solutions will be extremely low (Fox, 1978) and diffusion to plant roots will be extremely slow (Nye and Tinker, 1977). Phosphorus sources which are available for plants placed in bands or near the seed-row can improve P use efficiency by allowing the crop roots to access the P early in crop growth and by delaying the reaction of the P with calcium (Ca), magnesium (Mg) or with iron (Fe) or aluminum (Al) oxides (Sample *et al.*, 1980).

Phosphorus fertilization may also influence mycorrhizal development, with the effects being primarily related to the solubility and availability of the P fertilizers. While readily soluble and phytoavailable forms of P will rapidly increase P supply to the plant and decrease the mycorrhizal association, less-soluble forms of P such as rock phosphate have less effect on P supply to the plant and mycorrhizal association. Hence, mycorrhizal association may be especially important when less-soluble P forms are used for crop production (Grant *et al*., 2005).

With higher available soil P, application of fertilizer P may depress mycorrhizal association. Lower association may benefit crop growth by reducing the carbon drain to the fungi (Kahiluoto *et al*., 2001).

The specific absorption of P by functional groups can affect the charge balance and cause dispersion of particles (Lima *et al*., 2000). Mycorrhizal fungi contribute to soil structure by growth of external hyphae into the soil to create a structure that holds soil particles together and by creating the conditions of external hyphae that are conducive for the formation of micro-aggregates (Miller and Jastrow, 2000).

Though mycorrhizae can be used to mine soils for P uptake, it should not be claimed that mycorrhizal fungi are considered as biofertilizers. Contrary to rhizobia, which add external nitrogen (N) to the agroecosystem, AM fungi do not add phosphorus. But, their potential to liberate P that otherwise would have ended up in stable soil pools, implies that the role of AM fungi in enhancing uptake and efficiency of internal plants P pools and externally added P fertilizers, should not be neglected (Lehmann et al., 2001; Lekberg and Koide, 2005).

3.2 Effects of Arbuscular Mycorrhizal Fungi on Plant Growth

The extent to which the plant benefits from mycorrhizal association depends on its P requirement and inherent ability to forage for phosphate, on soil reserves of available phosphorus, and on the fungal species (Mosse and Hayman, 1980).

Under some conditions fertilizers with lower P availability might have practical advantages over more available forms if they were less inhibitory to mycorrhizal infection and could be made more accessible to the plant by an efficient mycorrhizal system (Mosse and Hayman, 1980). This applies particularly in tropical soils, such as Ultisols, with high 'phosphorus fixing' capacity where it is difficult to add sufficient phosphorus fertilizer to correct the naturally low phosphate status (Mosse and Hayman, 1980; Generose *et al*., 2002).

Mycorrhizae also have effects on disease resistance, soil aggregation, and transplanting. AM fungi are more capable than many other soil fungi to bind soil into semi-stable aggregates (Sutton and Sheppard, 1976).

AM fungi can alleviate Al toxicity. AM fungi improve water retention, especially under nutrient limitation. The extra-radical hyphae of AM fungi contribute to soil aggregation and structural stability. Therefore, mycorrhizae are multifunctional in agro-ecosystems (Newsham et al., 1995), potentially improving physical soil quality (through the external hyphae), chemical soil quality (through enhanced nutrient uptake) and biological soil quality (through the soil food web).

The association of AM fungi and plant is mutual benefit as the host plant supplies the fungi with photosynthetic products while the fungi assists the plant in its uptake of phosphate and other mineral nutrients from the soil (Harley and Smith, 1983; Marschner, 1995). Mycorrhizae enhance not only plant growth by improving nutrition (Smith and Gianinazzi-Pearson, 1988) but they also can buffer the plant against environmental stress (Sylvia and Williams, 1992) such as increased tolerance to certain pathogenic agents (Dehne, 1982), water stress (Subramanian *et al*., 1997), salinity (Bhoopander and Mukerji, 2004), low temperatures (Charest *et al*., 1993; Paradis *et al*., 1995) and pollution (Bagyaraj, 1995; Leyval *et al*., 1997).

AM plants have been reported to improve nutrition not only phosphorus but also other macronutrients such as nitrogen and potassium (K). In acid soils, AM fungi may be important for the uptake of ammonium ion (NH_4^+), which is less mobile than nitrate ion (NO_3^-) and where diffusion may limit its uptake rate. Because of their small size, AM fungal hyphae are better able than plant roots to penetrate decomposing organic materials (Hodge, 2003), and concentration of K were higher in mycorrhizal than in non-mycorrhizal plants (Bressan et al., 2001; Liu et al., 2002). Increased K concentrations can be a consequence of increased P availability on plant growth.

From experimental investigation with maize and wheat, Toth *et al*. (1990) and Hetrick *et al*. (1992) hypothesized that increasing resistance of crops to fungal pathogens by plant breeding decreases the benefit from AM fungi symbiosis. These results suggested that, in some cases, crop improvement reduces the response of crops to AM fungi (Pitakdantham *et al*., 2007).

AM fungi have the potential to reduce damage caused by soil-borne pathogenic fungi, nematodes, and bacteria. Interaction between AM fungi and nematodes have been studied in banana (*Musa* spp.). Jaizme-Vega *et al*. (1997) stated that inoculation with the fungus *Glomus mosseae* increased banana (*Musa* spp.) yield and reduced the reproduction of the root-knot nematode (*Meloidogyne* spp.) (Pinochet *et al*., 1997).

3.3 Effects of Arbuscular Mycorrhizal Inoculation

Arbuscular Mycorrhizae usually increase the growth of plants solely by enhancing nutrient uptake. There are three possible explanations for the greater uptake of mineral nutrients by mycorrhizal plants compared to nonmycorrhizal plants

(Rhodes and Gerdemann, 1980). Firstly, mycorrhizae may increase nutrient uptake by reducing the distance that nutrients must diffuse to plant roots (Rhodes and Gerdemann, 1975). Secondly, mycorrhizal roots may differ from nonmycorrhizal roots in the relationship between rate of nutrient absorption and nutrient concentration at the absorbing surface (Cress *et al*., 1979). Finally mycorrhizal hyphae may chemically modify the availability of nutrients for uptake by plants (Abbott and Robson, 1982).

From a consideration of the published evidence (Grant *et al*., 2001; Robin, 2003) it is likely that arbuscular mycorrhiza increases nutrient uptake from soil primarily by shortening the distance that nutrients must diffuse through soil to the root. It is likely, therefore, that effects of mycorrhizae in increasing nutrient uptake will be most marked for nutrients which move to roots principally by diffusion (Nye and Tinker, 1977) and for plant species with coarse roots and sparse short root hairs (Baylis, 1975).

Several recent reviews have dealt with the role of mycorrhizal associations in soil quality and sustainable agriculture (Dodd, 2000; Barea *et al*., 2002; Jeffries *et al*., 2002; Ryan and Graham, 2002; Harrier and Watson, 2003). These reviews generally focused on temperate soils. In reviewing the role of mycorrhizae in tropical soil fertility, the following two reasons are important (Sieverding, 1991). Firstly, soils, major crops and possibly the species composition of AM fungal communities are different between the major climatic zones, because mycorrhizal functioning depends on the interplay between fungi and plants, different perspectives may arise from temperature and tropical views. Secondly, agriculture in temperate regions is often characterized by excess amounts of nutrients and that in tropical regions is characterized by its difficulty of using nutrients due to their insufficient amounts (Van Noordwijk and Cadish, 2002).

Not all the soils chosen for inoculation experiments were extremely P deficient and results indicated that inoculation responses can often be better in moderately fertile soils (Mosse and Hayman, 1980). Adding 90 kilograms of phosphorus per hectare (as basic slag) increased clover response to inoculation by 118 percent (Hayman and Mosse, 1979). Inoculation responses of onion and lucerne, but not of barley, were greater in a field soil with 14 milligrams per kilogram available phosphorus (Olsen *et al*., 1954) than with 10 milligrams per kilogram (Owusu-Bennoah and Mosse, 1979).

To benefit from mycorrhizal associations, emphasis has to be on agricultural practices that promote the occurrence and functioning of soil organisms, including AM fungi. It has been shown that in fragile tropical agro-ecosystems, relying on tillage and external inputs such as fertilizers and biocides for the increase of productivity, may result in large ecological disturbances, and may not be sustainable in the long term (Irene and Thomas 2006). A key point for the development of a more self-sufficient and sustaining agriculture is a better understanding of the nature of agro-ecosystems and the principles by which they function (Altieri, 2004).

Whereas the role of mycorrhizal associations in enhancing nutrient uptake will mainly be relevant in lower input agro-ecosystems, the mycorrhizal role in maintaining soil structure is important in all ecosystems (Ryan and Graham, 2002). Its role on formation and maintenance of soil structure will be influenced by soil properties, root architecture and management practices (Irene and Thomas 2006).

4. Land Resources in Thailand

There are 4 main problems of land resources in Thailand (Land Development Department, 2006). The first is misuse of land. The others include residential and industrial construction on agricultural land, deforestration and encroachment into watershed conserved area, cultivation of plants that are not suitable to land. The total area of misused land is amounted to 4.8 million hectares. The second is the result of land mismanagement such as soil erosion and low organic matters. The former is accounted approximately 17.1 million hectares or 33 percent of the whole country and the latter is commonly found covering as high as 30.6 million hectares or 59.5 percent of the total area in the country. The third is topology and environment such as coastal land area, peat area, and old mining soil. In coastal land area, a total of 1.6 million hectares is not fully productive. The problem is mainly contributed from the characteristics of soil itself as well as the natural environment of that area.

Peat area is severely flooded all year round and contains too much organic matters. Old mining soil is mainly gravelly soil, which fertility is too low and structure is not suitable for cultivation. The last is problem soils such as acid soil, saline soil, and acid saline soil. In the central low land region, there are 7 provinces facing acid soil problem. The area of severely acid to moderately acid soil is 3,680 km^2 with the average yield of rice at 938 kilograms per hectare. In the northeastern part of Thailand, saline soils cover 2.85 million hectares. Of these, 0.24 million hectares are severely affected, characterized by salinity in surface soil and shallow saline groundwater (Arunin, 1984). In the south, there are as much as 0.4 million hectares of saline soil and 0.16 million hectares of acid soil. Thirty percent of the saline soil and almost one hundred of these acid soils are either used as paddy field or left unused. The average yield from this kind of soil is only 938-1,875 kilograms per hectare (Land Development Department, 2006).

Sandy soils are generally regarded as very fragile with respect to agricultural production due to their very low nutrients and organic matter content (Buol *et al*., 2003; Wambeke, 1992). Agricultural productivity on such soil is hence considerably low.

In Northeast Thailand, for example, agricultural systems have been developed on such sandy soils and paddy rice has been cultivated in the lowlands and various field crops such as maize, cassava and sugarcane have been cultivated in the uplands (Yanai *et al*., 2005). After continuous cultivation of such crops, yield decline has been observed mainly in the uplands. Decline in soil fertility has also been related to the decline of soil nutrients and organic matter. Nevertheless, limited information is available on the fertility status of soils especially with reference to soil-plant relationship, even though analysis of nutrient balance or soil-plant nutrient budget is important and inevitable to assess the sustainability of agricultural ecosystem (Vidhaya *et al*., 2004).

Weathered tropical soils, such as Oxisols, present desirable physical characteristics. However, soil management can lead to degradation of soil aggregation due to dispersion of particles, decrease in size of the aggregates, increase in the density, movement of clay in the horizon and decrease in macro-porosity (Irene and Thomas 2006).

5. Baby Corn (*Zea mays* L.) Growth

There are two different methods for producing baby corn (*Zea mays* L.). In the first method, baby corn (*Zea mays* L.) is the primary crop, and a variety is selected and planted to produce only baby corn (*Zea mays* L.). In the second method, baby corn (*Zea mays* L.) is the secondary crop in a planting of sweet corn (Galinat, 1985). The decision whether to grow baby corn (*Zea mays* L.) either as primary crop or as a secondary crop will influence variety choice, planting density and fertilizer rates (Miles and Zenz, 2000).

When selecting a corn variety for baby corn (*Zea mays* L.) production, ear appearance is very important. Ears should be 5 to 10 centimeters long and 0.7 to 1.7 centimeters in circumference at the harvest (Chutkaew and Paroda, 1994). To meet these criteria, harvest ears 1 to 3 days after silks become visible (Bar-Zur and Saadi, 1990). Prior to planting, plow and harrow soil as needed to form a smooth, level seed bed. Well-drained soils warm faster and are less likely to have soil-borne diseases. Baby corn (*Zea mays* L.) seeds are planted at 2.5 to 5 centimeters depth (Miles and Zenz, 2000).

The best soil for baby corn (*Zea mays* L.) is a well-drained with a texture of silt loam or loam type. It should be a type of a soil with a high moisture holding capacity, high amount of organic matter and be slightly acidic. The optimum pH range is from 5.3 to 7.3, and 400 to 600 mm of rainfall is required during growing period. In case of moisture deficiency, irrigation is essential (Lolita, 2007).

Land Development Department (2006) reported that baby corn can grow in almost every soil type but the most suitable soils should be well drained. A suitable pH of soils should be in a range between 5.5 and 7.0. However it can also grow well in a more acidic soil.

As with any planting of baby corn (*Zea mays* L.), it is necessary to keep the weeds suppressed until the baby corn have reached a height of 60 centimeters. Early weed control will delay baby corn maturity and reduce yield (Miles and Zenz, 2000). Generally baby corn requires practically no application of pesticides because the crop has a short growth duration (Lolita, 2007).

Hypothesis

1. The rate of phosphorus fertilizer must be low when mycorrhiza could work, and the rate of phosphorus fertilizer must be high when mycorrhiza could not work well.

2. Effects of AM fungi will increase under low fertility soils.

3. Under high fertility, soil and cultivation management would be more effective than arbuscular mycorrhizal inoculation.

MATERIALS AND METHODS

Materials

The materials need in the study include the followings;

1. pH meter
2. Spectrophotometer
3. Atomic absorption spectrophotometer (AAS)
4. Flame emission spectrophotometer
5. Microscope
6. Chemicals and glasswares for laboratory analyses
7. Agricultural materials and products for field experiment

Methods

1. Description of Field Site

The experimental plot was located at the Royal Development Study Center in Khao Hin Son, Phanom Sarakham district, Chachoengsao province and the soil is Chan Thuek (Cu) series (Typic Ustipsamments) (Hemsrichart, 1988; Soil Survey Staff, 2003). Chan Thuek series occupies small extent in the southern part of central highlands and in northern Thailand. Parent material of Chan Thuek series is local wash derived from weathered granite. The soil occurs on erosion surface of residual hill. Relief is undulating with slopes 2 to 5 percent. Elevation is 280 to 320 m above mean sea level. The climate is tropical savanna. Average annual precipitation varies from 1,100 to 1,300 mm, and annual air temperature is from 26 to 28 ^{o}C. Chan Thuek series is characterized by a very dark grayish brown or very dark brown loamy sand A horizon overlying a pale brown, light brown or pinkish gray loamy sand over gravelly loamy sand C horizon. Reaction is medium acid to strongly acid throughout the profile (Hemsrichart, 1988).

2. Sampling and Chemical Analysis

2.1 Soil Sampling

Soil samples for determining chemical properties were taken from a mixed soil which was collected from areas of 16 x 32 m and 30 cm depth in January 2007 (before planting) and in November 2007 (after harvest). The soil samples were gently crushed and well mixed. Then they were air dried, sieve and stored in a plastic bag until determination of their chemical properties.

2.2 Soil Analysis

Soil samples were analyzed for soil reaction (pH), organic matter content, exctractable bases (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}), cation exchange capacity (CEC), electrical conductivity (EC), available P and total nitrogen. The soil reaction (pH) was measured with pH meter by 1:1 soil solution in H_2O and 1M KCl (Peech, 1965). Organic matter content was determined by wet digestion and titration, Walkley-Black method (Nelson and Sommers, 1996). Extractable bases (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) were analyzed by 1M NH_4OAc at pH 7.0 extraction and measured by AAS and flame emission spectrophotometer (Thomas, 1982). CEC was determined by saturating the exchange site and displacing by 1M NH_4OAc at pH 7.0 and NaCl respectively (Rhoades, 1982). EC was measured by EC saturation (Thomas, 1982). Available P was measured colorimetrically with a spectrophotometer using Bray II method (Bray and Kurtz, 1945). And total nitrogen was determined by digestion of the sample to convert organic N to NH_4^{+}-N and determination of NH_4^{+}-N by Kjeldahl method (Bremmer, 1965).

3. Experimental Design

Field experiment was conducted using 4×2 factorial treatment combinations with 4 replications in a randomized complete block design. The experimental treatments were factorial combinations of 2 factors as follows:

Factor 1: Rate of fertilizer application

1) T_1: No phosphorus fertilizer
2) T_2: phosphorus fertilizer equivalent to 60 kg P_2O_5 ha^{-1} on a surface
3) T_3: phosphorus fertilizer equivalent to 120 kg P_2O_5 ha^{-1} on a surface
4) T_4: phosphorus fertilizer equivalent to 240 kg P_2O_5 ha^{-1} on a surface

Factor 2: AM fungal inoculation treatments

1) I_1: Not inoculated
2) I_2: Inoculated with *Glomus*

4. Fertilization and Inoculum Procedures

Before planting, 5 kilograms of organic fertilizer composing of 1,030 g of total-N, 1,560 g of total-P and 840 g of total-K were applied for each plot. And two croppings, Crop 1 and Crop 2 were running parallelly at the same period.

One plot is 4 x 2 m, and there were 48 holes per plot with four maize seeds. Twelve holes per plot of baby corn were cultivated. The rates of P fertilizer were T_1, T_2, T_3 and T_4 representing 0, 96, 192 and 384 g P_2O_5 per plot, respectively (equivalent to 0, 60, 120 and 240 kg P_2O_5 per hectare). And 192 g of urea (46 % $(NH_2)_2CO$) and 144 g of potassium chloride (60 % KCl) were applied two times to each plot. The first half of fertilizer was applied at planting. The *Glomus* inoculum was obtained from the Department of Microbiology, Faculty of Science, Kasetsart University. A ten grams of soil inoculum of AM fungi was put in one hole. Then it was covered with soil. Irrigation was dependent on rain-fed. And when it did not rain for 3 days running, the field was irrigated every 5 days with about 10 L per plot. At 28 days after planting, the second half of the N, P and K fertilizers were applied on the soil surface around the plant.

5. Data Collection

The plants were harvested at 66 days after planting. Shoot height, circumference and shoot fresh weight were measured at harvest. Dry matter of shoot was measured after drying in oven at 70 ^{o}C, then they were ground for wet ashing to analyze for P and K. And for N, samples were analyzed by Kjeldahl method.

After harvest, percent root colonization was determined by the Trouvelot's method (Trouvelot, 1986). The cleared and stained roots were cut into 1 cm length, and laid down on a microscope slide to determine colonization. The percent of root colonization was calculated as follows:

$$\% \text{ colonization (M)} = \frac{95(n_5)+70(n_4)+30(n_3)+5(n_2)+n_1}{n}$$

where n is the number of observed roots, n_1 is the number of roots that showed less than 1 percent of infection, n_2 is the number of roots that showed less than 10 percent of infection, n_3 is the number of roots that showed from 11 to 50 percent of infection, n_4 is the number of roots that showed from 51 to 90 percent of infection, and n_5 is the number of roots that showed more than 90 percent of infection.

6. Statistical Analysis

Two factor analyses of variance (ANOVA) and Duncan multiple range test were used to partition the variance into the main effects and the interaction between mycorrhizal colonization and fertilizers.

7. Places and Duration

Soil sampling and laboratory analysis before planting were conducted from January to February in 2007. Field experiment was conducted from September to November in 2007 at the Royal Development Study Center in Khao Hin Son, Phanom Sarakham district, Chachoengsao province. Chemical analysis of soil and baby corn (*Zea mays* L.) were done after harvest, from November 2007 to February 2008 at the Department of Soil Science, Faculty of Agriculture, Kasetsart University. And quantification of AM fungi colonization was conducted from April to May in 2008 at the Department of Microbiology, Faculty of Science, Kasetsart University.

RESULTS AND DISCUSSION

1. Soil Chemical Properties Prior to the Experiment

Soil samples for determining chemical properties were taken from areas of 16 x 32 m and 30 cm depth. Table1 shows the chemical properties of soil prior to experiment. According to this table, pH was slightly acid, organic matter (OM) contained very low. And topsoil contained more extractable bases except for potassium (K).

Table 1 Chemical properties of soil prior to experiment.

		Available		Extractable					
Depth	pH	OM	P	Ca	Mg	K	Na	CEC	BS
(cm)	1:1 soil:H_2O	g kg^{-1}	mg kg^{-1}	(--------------------------		cmol kg^{-1}		------------------------)	%
0-15	5.4	9.3	17.57	0.18	0.02	0.008	0.12	0.24	144
15-30	5.4	4.1	1.86	0.02	0.002	0.01	0.09	0.13	67

2. Soil Chemical Properties After Harvest

Table 2 shows chemical properties after harvest for A horizon (0-18cm) and AC horizon (18-30cm). For crop 1, treatment I_2 (not inoculated *Glomus*) had higher pH than treatment I_1 (inoculated *Glomus*), and available P was also higher in treatment I_2 than in treatment I_1. As to crop 2, Available P increased when *Glomus* was inoculated only in treatments T_2 and T_4. And treatment I_2 had higher CEC than did I_1.

Comparing Crop 1 and Crop 2, Crop 1 showed different result of each chemical property between treatments I_1 and I_2, while Crop 2 showed similar trend between treatments I_1 and I_2. This indicates that inoculation did not have effect on baby corn (*Zea mays* L.) growth for Crop 2.

Analytical data prior to experiment and after harvest (Table 1 and 2) showed that pH of topsoil increased in every treatments of Crop 1 and Crop 2. On the other hand, pH of subsoil decreased in some treatments. Those were T_1I_1, T_4I_1 and T_3I_2 of Crop 1, and T_1I_1, T_2I_1, T_3I_1, T_4I_1, T_1I_2, T_2I_2 and T_3I_2 of Crop 2. Available P of topsoil and subsoil increased in each treatment of Crop 1 and Crop2. Extractable K of topsoil increased in each treatment of Crop 1 and Crop 2, while extractable K of subsoil did not increase except for T_3I_2 of Crop 1. Extractable Ca of topsoil and subsoil increased in each treatment of Crop 1 and Crop 2. Extractable Mg of topsoil and subsoil increased in each treatment of Crop 1 and Crop 2 except for T_3I_2 of Crop 1. CEC of topsoil and subsoil increased in each treatment of Crop 1 and Crop 2.

3. Germination Rate

Germination rate was calculated seven days after planting for both Crop 1 and Crop 2 (Table 3). For Crop 1, regardless of P fertilizer rate, replication 4 had the lowest germination rate. This could be due to the uneven moisture condition in the plot. And mean germination rate of Crop 2 was higher than that of Crop 1 in each treatment.

Table 2 Chemical properties after harvest for A horizon (0-18cm) and AC horizon (18-30cm).

Fertilizer rate kg P_2O_5 ha^{-1}	Horizon	pH soil:H_2O	Available P mg kg^{-1}	Extractable K	Extractable Ca	Extractable Mg	CEC
				(----------------------------	c mol kg^{-1}	----------------------------	)
Not Inoculated (I_1)							
Crop 1							
0 (T_1)	A	5.8	47.64	0.02	0.55	0.07	1.00
	AC	5.2	8.59	0.01	0.15	0.02	0.60
60 (T_2)	A	5.7	24.54	0.02	0.41	0.07	1.20
	AC	5.5	8.95	0.01	0.15	0.03	0.60
120 (T_3)	A	5.5	47.67	0.02	0.54	0.09	0.70
	AC	5.4	6.83	0.01	0.12	0.02	0.50
240 (T_4)	A	5.8	25.81	0.03	0.54	0.11	1.30
	AC	5.0	5.06	0.01	0.07	0.02	0.90
Crop 2							
0 (T_1)	A	5.9	21.71	0.03	0.30	0.10	0.90
	AC	5.2	3.64	0.01	0.04	0.01	0.30
60 (T_2)	A	5.6	19.58	0.02	0.27	0.07	1.00
	AC	5.2	6.83	0.01	0.05	0.01	0.50
120 (T_3)	A	5.6	29.34	0.02	0.22	0.05	0.90
	AC	5.2	6.48	0.01	0.06	0.01	0.50
240 (T_4)	A	5.6	18.87	0.02	0.31	0.05	1.00
	AC	5.1	7.54	0.01	0.08	0.01	0.70
Inoculated (I_2)							
Crop 1							
0 (T_1)	A	6.0	68.32	0.04	0.57	0.11	0.85
	AC	5.6	5.41	0.01	0.14	0.02	0.20
60 (T_2)	A	5.9	41.98	0.04	0.54	0.08	0.85
	AC	6.0	7.89	0.01	0.14	0.03	0.50
120 (T_3)	A	5.0	42.00	0.01	0.44	0.02	0.45
	AC	5.6	6.83	0.02	0.11	0.05	0.80
240 (T_4)	A	5.9	43.42	0.03	0.62	0.10	1.55
	AC	5.4	7.19	0.01	0.07	0.02	0.70
Crop 2							
0 (T_1)	A	5.5	20.99	0.03	0.25	0.07	1.10
	AC	4.7	2.93	0.01	0.03	0.01	1.05
60 (T_2)	A	5.7	31.38	0.02	0.35	0.09	1.15
	AC	5.0	5.77	0.01	0.06	0.01	0.70
120 (T_3)	A	5.4	18.88	0.02	0.19	0.05	1.15
	AC	5.2	6.83	0.01	0.06	0.02	0.50
240 (T_4)	A	5.9	36.44	0.02	0.38	0.09	1.05
	AC	5.4	8.95	0.01	0.07	0.02	0.90

Table 3 Germination rates of baby corn (*Zea mays* L.) for Crop 1 and Crop 2.

P_2O_5 (kg ha^{-1})	AMF[1/]	Replication	Germination rate (%)	
			Crop 1	Crop 2
0	no AMF	1	88	65
		2	81	100
		3	98	94
		4	33	88
		Mean	75	86.75
	with AMF	1	77	65
		2	96	88
		3	94	98
		4	54	90
		Mean	80.25	85.25
60	no AMF	1	77	98
		2	100	90
		3	79	92
		4	46	81
		Mean	75.5	90.25
	with AMF	1	98	77
		2	96	94
		3	94	98
		4	48	83
		Mean	84	88
120	no AMF	1	94	96
		2	77	94
		3	90	98
		4	52	83
		Mean	78.25	92.75
	with AMF	1	79	85
		2	73	96
		3	96	100
		4	50	79
		Mean	74.5	90
240	no AMF	1	81	69
		2	96	85
		3	88	94
		4	48	79
		Mean	78.25	81.75
	with AMF	1	90	67
		2	83	85
		3	85	98
		4	65	98
		Mean	80.75	87

[1/]AMF=Arbuscular mycorrhizal fungi

4. Effects of AM Fungi Inoculation and P on Baby Corn (*Zea mays* L.) Growth

Table 4 shows F-values from ANOVA of baby corn (*Zea mays* L.) height, shoot circumference, fresh weight and dry weight with AM fungi inoculation and four rates of P fertilizer of Crop 1 and Crop 2. According to this table, inoculation had a highly significant effect ($p<0.01$) on shoot height, fresh weight for Crop1. And it also had a significant effect ($p<0.05$) on dry weight. Fertilizer rate had a highly significant effect ($p<0.01$) on shoot height, fresh weight and dry weight. On the other hand, there was no significant interaction between inoculation and fertilizer rate. For Crop 2, fertilizer rate had a significant effect ($p<0.01$) on shoot height, and also it had a significant effect ($p<0.05$) on shoot fresh weight. But there was no significant interaction between fertilization and AM fungi inoculation.

Table 4 F-values from ANOVA of baby corn (*Zea mays* L.) height, shoot circumference, fresh weight and dry weight with AM fungi inoculation and four rates of P fertilizer for Crop 1 and Crop 2.

		F-values			
Source	df	Height	Shoot Circumference	Fresh weight	Dry weight
Crop 1					
Block	3	10.15**	2.02ns	6.36**	2.26ns
Inoculation (I)	1	10.98**	0.69ns	12.38**	5.02*
Fertilizer (T)	3	4.91**	0.50ns	4.80**	4.73**
I × T	3	2.66ns	1.28ns	1.24ns	0.49ns
CV (%)		24.9	20.0	34.4	38.4
Crop 2					
Block	3	1.25ns	2.77ns	2.69ns	1.48ns
Inoculation (I)	1	0.99ns	0.66ns	0.29ns	1.56ns
Fertilizer (T)	3	3.30**	0.31ns	3.01*	1.22ns
I × T	3	0.78ns	3.11ns	0.91ns	0.81ns
CV (%)		28.9	10.3	33.8	36.8

**=significant at 99% level,*=significant at 95% level, ns=non significant

5. Effects of Phosphorus Fertilizer on height, circumference, fresh weight and dry weight of shoot

According to Duncan's multiple range test, the most efficient amount of P_2O_5 was at 60 kilograms per hectare for both Crop 1 and Crop 2 (Table 5). Application of AM fungi together with P fertilizer was more effective in increasing dry matter weight of shoot of baby corn (*Zea mays* L.) than that of application P fertilizer alone for Crop 1. Crop 2 showed similar trend as Crop 1 except for 60 kilograms P_2O_5 per hectare (Figure 1 a). Application of AM fungi together with P fertilizer was also more effective in increasing shoot height and shoot P content of baby corn (*Zea mays* L.) than that of application P fertilizer alone for Crop 1. And Crop 2 showed similar trend as Crop 1 except for 120 kilograms P_2O_5 per hectare (Figure 1 b, c).

Table 5 Effect of P fertilizer rate on baby corn (*Zea mays* L.) height, shoot circumference, fresh weight and dry weight from Duncan's multiple range test for Crop 1 and Crop 2.

Fertilizer rate (kg P_2O_5 $ha^{-1)}$	Height (cm)	Shoot circumference (cm)	Fresh weight (kg ha^{-1})	Dry weight (kg ha^{-1})
Crop 1				
0	31.7b	2.96	6,229b	1,446b
60	47.6a	3.33	10,208a	3,083a
120	50.1a	3.26	11,125a	2,677a
240	40.2ab	3.22	10,611a	2,269ab
Crop 2				
0	29.2b	2.78	5,286b	2,047ab
60	39.7ab	2.75	8,083ab	1,963b
120	36.3ab	2.71	8,694ab	2,194ab
240	46.0a	2.84	9,819a	2,675a

Values are means (n=4 × 2 × 24 plants). Means in a column followed by the same letter are not significantly different ($p<0.05$) based on Duncan's multiple range test.

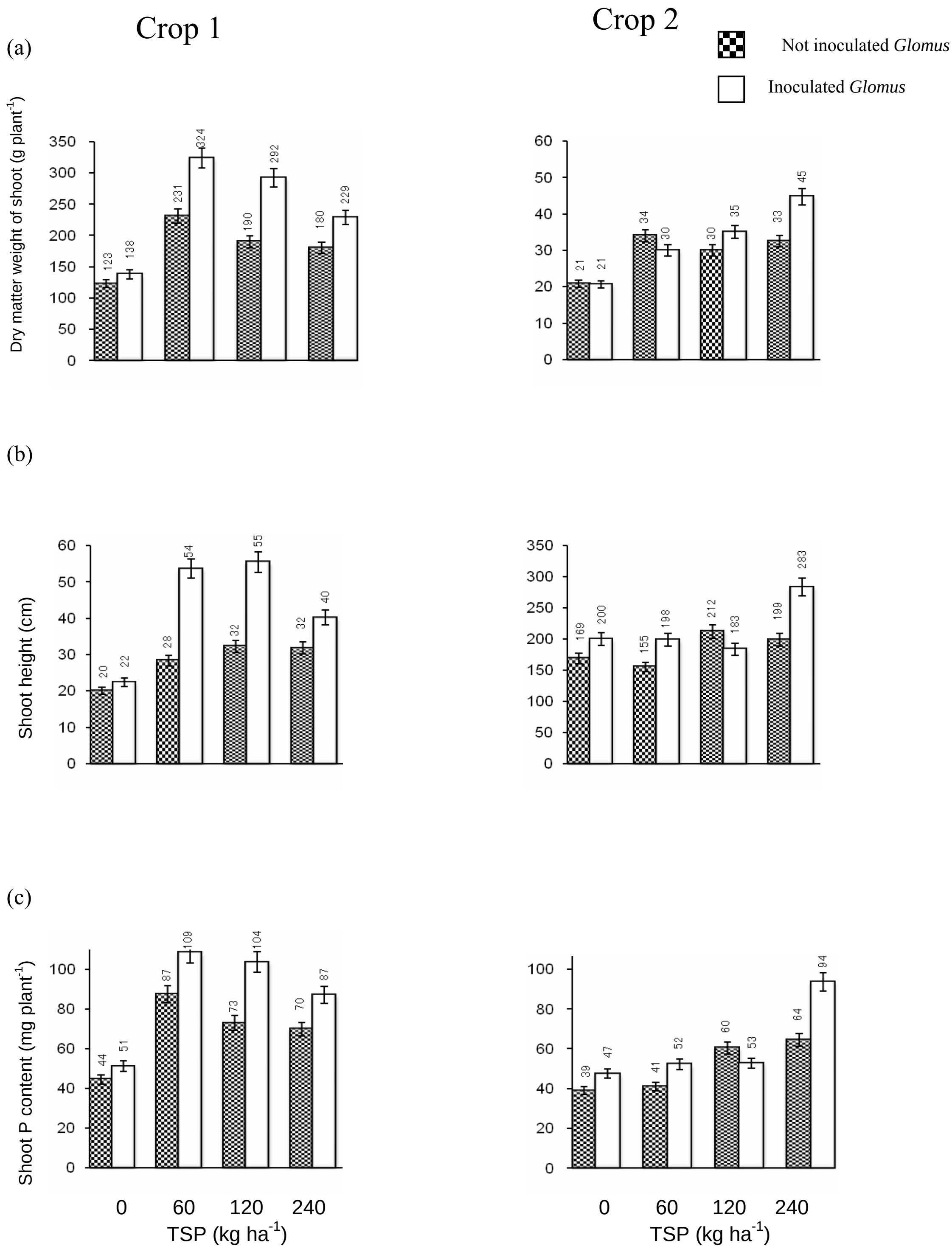


Figure 1 Mean comparison of dry matter weight of shoot (a), shoot height (b) and shoot P content (c) of baby corn (*Zea mays* L.) for Crop 1 and Crop 2.

6. Effects of AM Fungi Inoculation at Different P Fertilization Treatments on Baby Corn (*Zea mays* L.) Growth

There was a significant correlation between shoot P content and dry matter weight of shoot (R^2= 0.94) with linear approximate equation for Crop 1(Figure 2 a). The correlation between shoot P content and dry matter weight of shoot was calculated for each rate of P as R^2= 0.87 (Figure 3 a), R^2= 0.94 (Figure 3 b), R^2= 0.88 (Figure 3 c), R^2= 0.98 (Figure 3 d) for 0, 60, 120 and 240 kilograms P_2O_5 per hectare, respectively.

There was a significant correlation between shoot P content and dry matter weight of shoot (R^2= 0.82) with linear approximate equation for Crop 2 (Figure 2 a). The correlation between shoot P content and dry matter weight of shoot was calculated for each rate of P as R^2= 0.93 (Figure 3 e), R^2= 0.97 (Figure 3 f), R^2= 0.85 (Figure 3 g) R^2= 0.76 (Figure 3 h) for 0, 60, 120 and 240 kilograms P_2O_5 per hectare, respectively.

There was a significant correlation between root colonization and shoot P content (R^2= 0.31) with linear approximate equation for Crop 1 (Figure 2 b). The correlation between root colonization and shoot P content was calculated for two rates of P as R^2= 0.76 (Figure 4 a) and R^2= 0.10 (Figure 4 b) for 0 and 60 kilograms P_2O_5 per hectare, respectively.

There was a significant correlation between root colonization and shoot P content (R^2= 0.14) with linear approximate equation for Crop 2 (Figure 2 b). The correlation between root colonization and shoot P content was calculated for two rates of P as R^2= 0.84 (Figure 4 a) and R^2= 0.18 (Figure 4 b) for 0 and 60 kilograms P_2O_5 per hectare, respectively.

There was a significant correlation between root colonization and dry matter weight of shoot (R^2=0.37) with linear approximate equation for Crop 1 (Figure 2 c). The correlation between root colonization and dry matter weight of shoot was calculated for two rates of P as R^2= 0.73 (Figure 4 c) and R^2= 0.17 (Figure 4 d) for 0 and 60 kilograms P_2O_5 per hectare, respectively.

There was a significant correlation between root colonization and dry matter weight of shoot (R^2= 0.12) with linear approximate equation for Crop 2 (Figure 2 c). The correlation between root colonization and dry matter weight of shoot was calculated for two rates of P as R^2= 0.82 (Figure 4 c) and R^2= 0.10 (Figure 4 d) for 0 and 60 kilograms P_2O_5 per hectare, respectively.

Figures 5 and 6 showed plant conditions at harvest (66 days after planting) for Crop 1and Crop 2, respectively. The lowest cultivation rate of Crop 1 was replication 4, and it is in proportion to germination rate (Table 3).

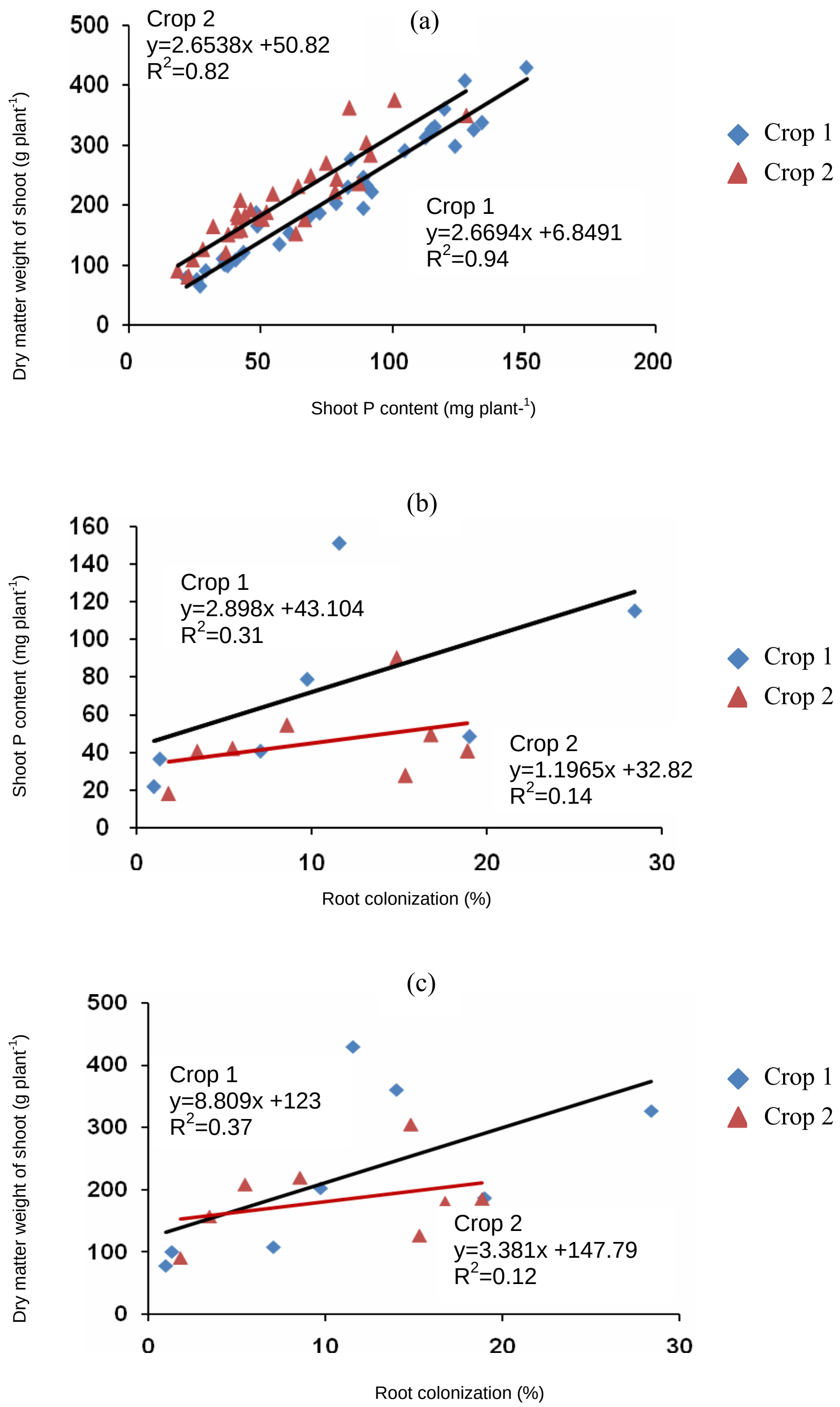


Figure 2 Relationship between shoot P content and dry matter weight of shoot (a), root colonization and shoot P content (b) and root colonization and dry matter weight of shoot (c) across all fertlizer treatments. The line is a linear approximate equation.

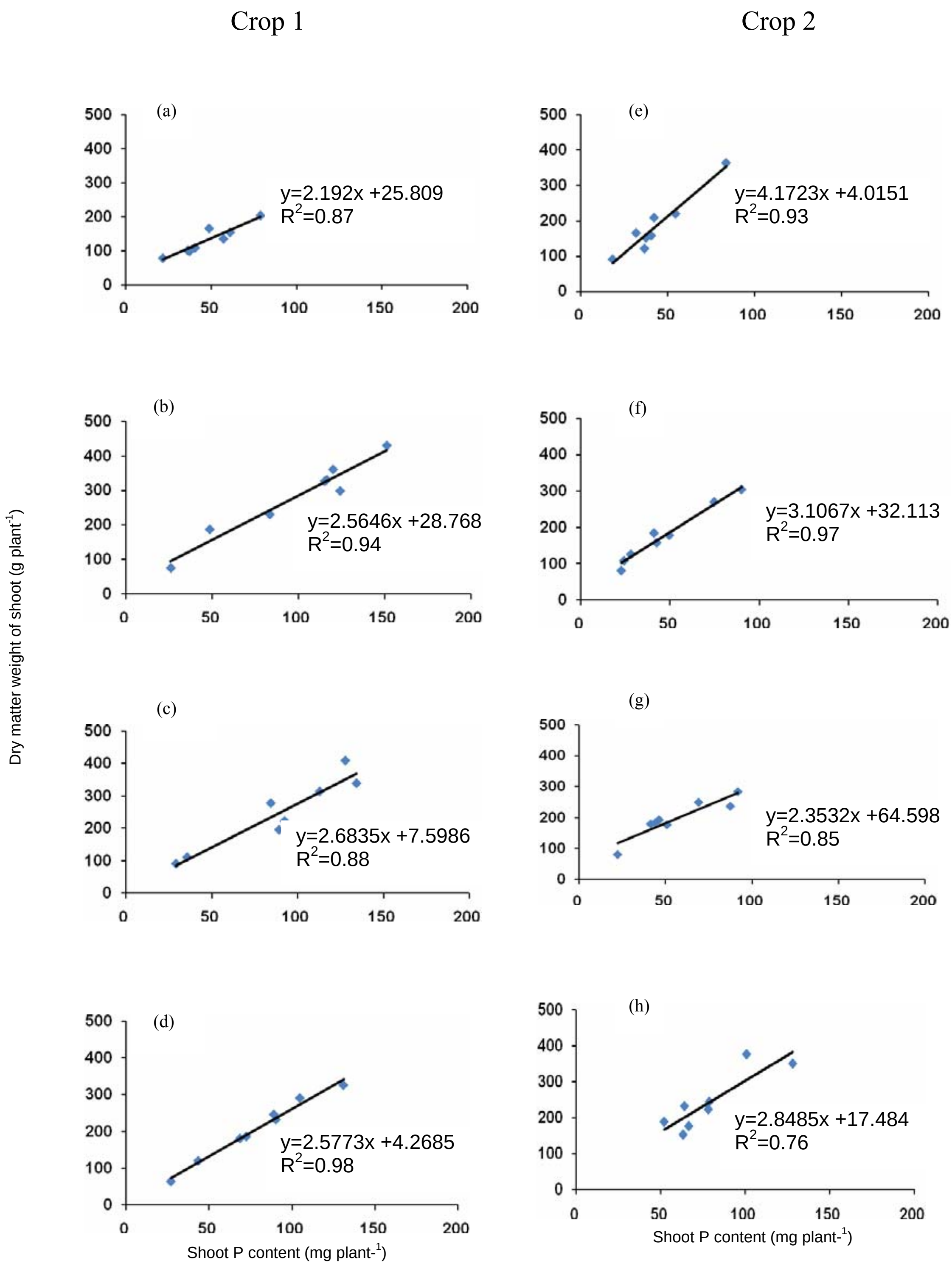


Figure 3 Relationship between shoot P content and dry matter weight of shoot at 0 (a, e), 60 (b, f), 120(c, g) and 240(d, h) kg P_2O_5 $ha^{-1}$for Crop 1 and Crop 2. The line is a linear approximate equation.

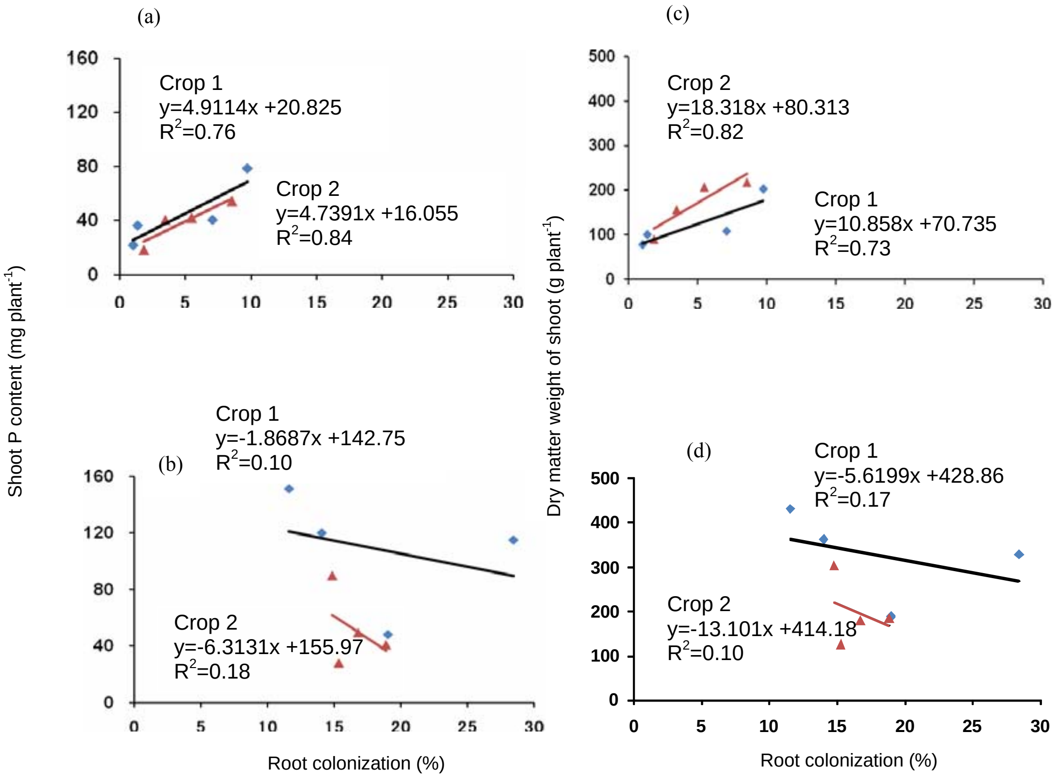


Figure 4 Relationship between root colonization and shoot P content, root colonization and dry matter weight of shoot at T_1I_1 (0 kg P_2O_5 ha^{-1}, not inoculated *Glomus*) (a, c) and T_2I_2 (60 kg P_2O_5 ha^{-1}, inoculated *Glomus*) (b, d). The line is a linear approximate equation.

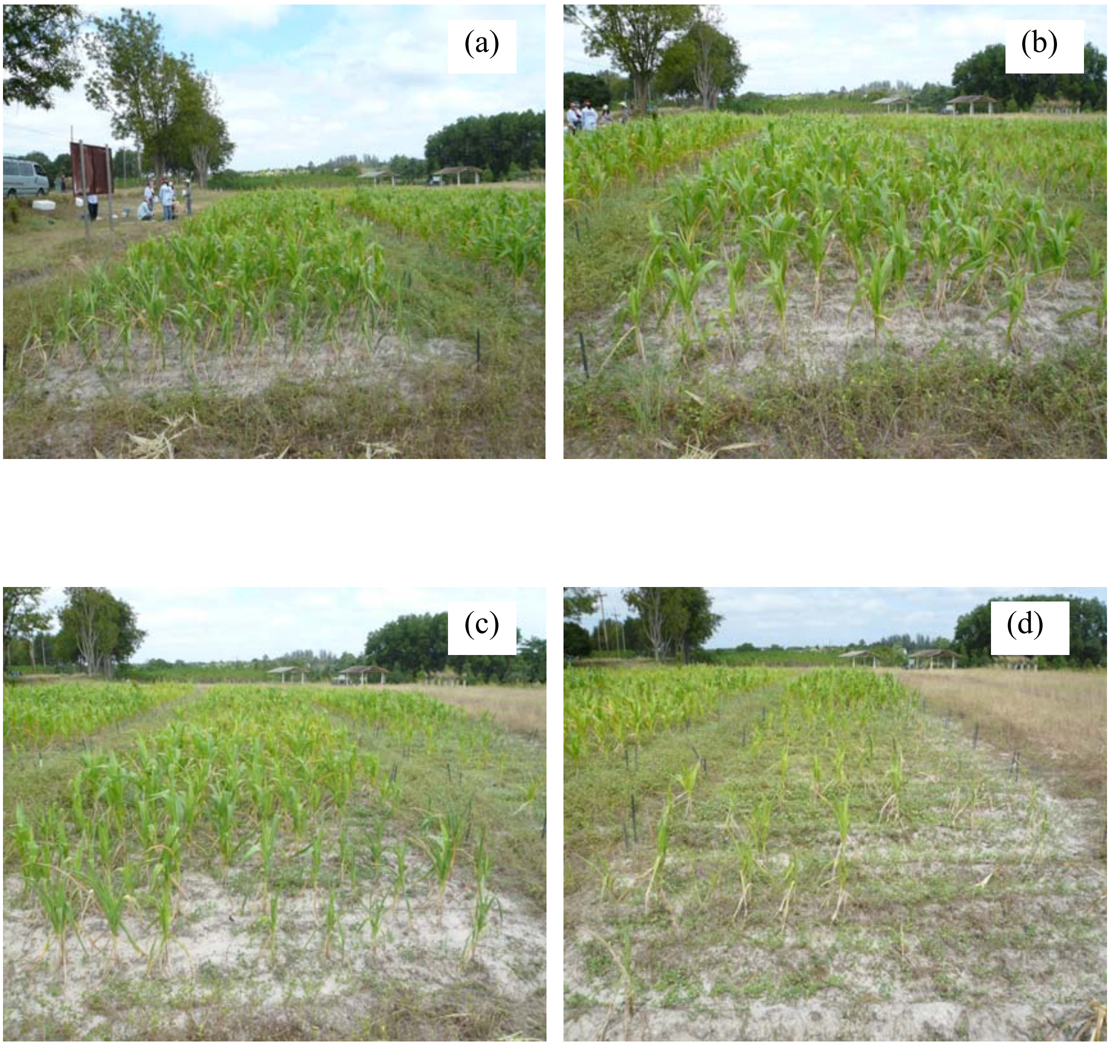


Figure 5 Plant conditions at harvest (66 days after planting) of replication 1(a), 2(b), 3(c) and 4(d) area for Crop 1.

Figure 6 Plant conditions at harvest (66 days after planting) of replication 1(a), 2(b), 3(c) and 4(d) area for Crop 2.

7. Effects of AM Fungi Inoculation and Nutrient Concentration on Baby Corn (*Zea mays* L.) Growth

For both Crop 1 and Crop 2, there was no significant ($p>0.05$) interaction between phosphorus fertilizer and AM fungi inoculation on nutrient (nitrogen, phosphorus and potassium) concentration as shown in Table 6. However, inoculation had a significant effect ($p<0.05$) on nitrogen concentration for Crop 1 (Table 6).

Table 6 F-values from ANOVA of nutrient concentration of baby corn (*Zea mays* L.) with AM fungi inoculation and four rates of P fertilizer for Crop 1 and Crop 2.

Source	df	F-value		
		N	P	K
Crop 1				
Block	3	1.14ns	1.36ns	1.56ns
Inoculation (I)	1	7.43*	2.96ns	2.82ns
Fertilizer (T)	3	2.03ns	1.97ns	2.77ns
I × T	3	0.32ns	0.54ns	0.80ns
Crop 2				
Block	3	1.13ns	1.14ns	0.45ns
Inoculation (I)	1	0.20ns	0.34ns	2.10ns
Fertilizer (T)	3	1.67ns	1.52ns	2.06ns
I × T	3	0.77ns	0.80ns	2.58ns

8. Effects of Fertilization on AM Fungi Inoculation

Table 7 showed the comparison of percent of root colonization both T_1I_1 (no phosphorus fertilizer and not inoculated *Glomus*) and T_2I_2 (60 kilograms P_2O_5 per hectare and inoculated *Glomus*) across all replications. In every treatment, inoculation *Glomus* was more effective than not inoculated. Though T_1I_1 was not inoculated *Glomus*, it showed the root colonization. This indicates that native AM fungi existed in that treatment.

Figures 7 and 8 showed arbuscules on treatment T_1I_1 (no phosphorus fertilizer and not inoculated *Glomus*) and T_2I_2 (60 kilograms P_2O_5 per hectare and inoculated *Glomus*) of Crop 1 and Crop 2, respectively.

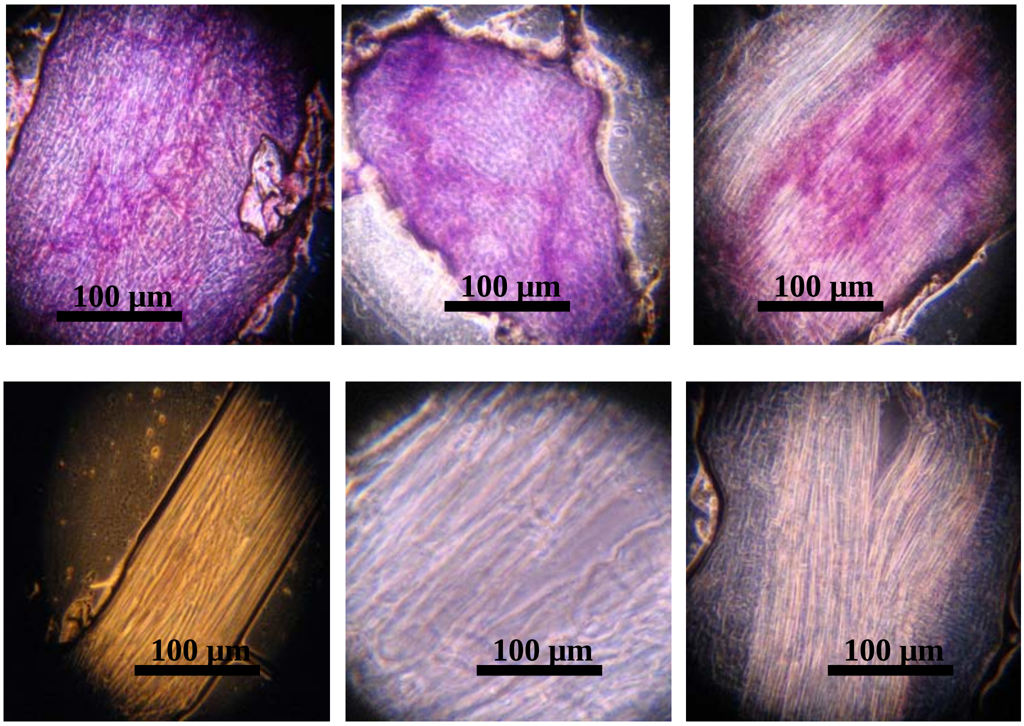
In general, arbuscules were stained in blue color, but some pictures showed purple. This is due to light when taking photo. And even though Treatment I_1 was not inoculated *Glomus*, some arbuscules were confirmed. They might be native AM fungi.

Table 7 The percent of root colonization for T_1I_1 and T_2I_2 for Crop1 and Crop 2.

Treatment	% M	
	Crop 1	Crop 2
$T_1I_1R_1$	7.08	3.46
$T_1I_1R_2$	9.74	8.57
$T_1I_1R_3$	1.00	5.47
$T_1I_1R_4$	1.34	1.82
Mean	4.79	4.83
$T_2I_2R_1$	14.03	16.77
$T_2I_2R_2$	11.57	18.86
$T_2I_2R_3$	19.00	14.83
$T_2I_2R_4$	28.42	15.32
Mean	18.26	16.45

T=fertilizer rate (T_1=0 kg P_2O_5 ha^{-1}, T_2=60 kg P_2O_5 ha^{-1}, T_3=120 kg P_2O_5 ha^{-1}, T_4=240 kg P_2O_5 ha^{-1}), I=inoculation (I_1=not inoculated *Glomus* I_2= inoculated *Glomus*).
R= replications % M=percent of root colonization.

(a)



(b)

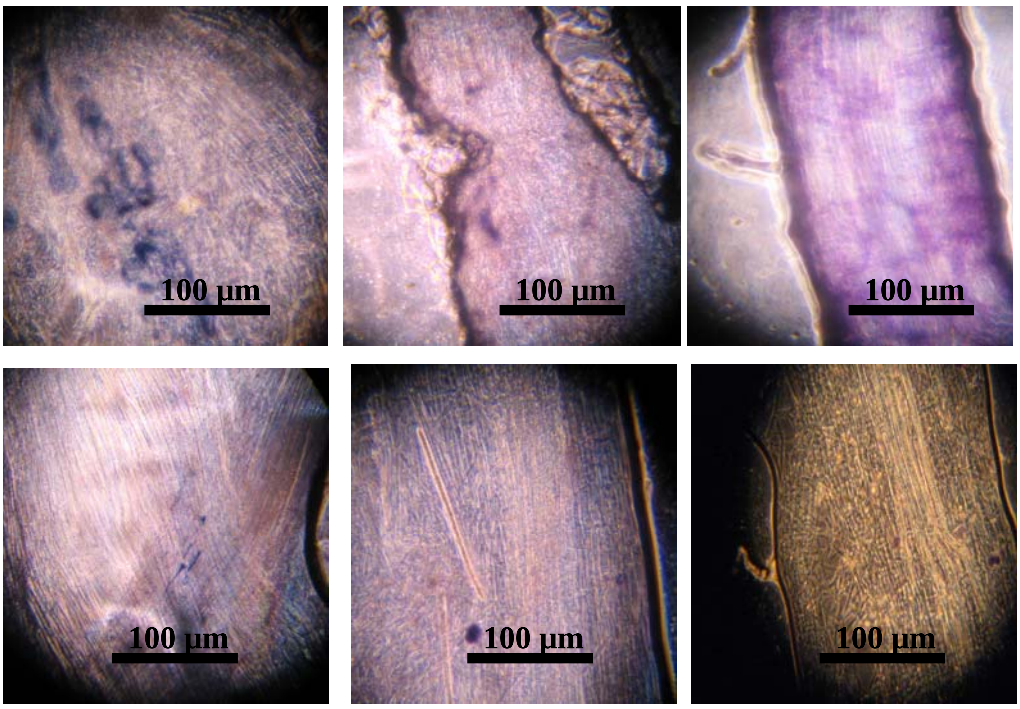


Figure 7 Feature of arbuscules of T_1I_1 (0 kg P_2O_5 ha^{-1}, not inoculated *Glomus*) for Crop 1 (a) and Crop 2 (b).

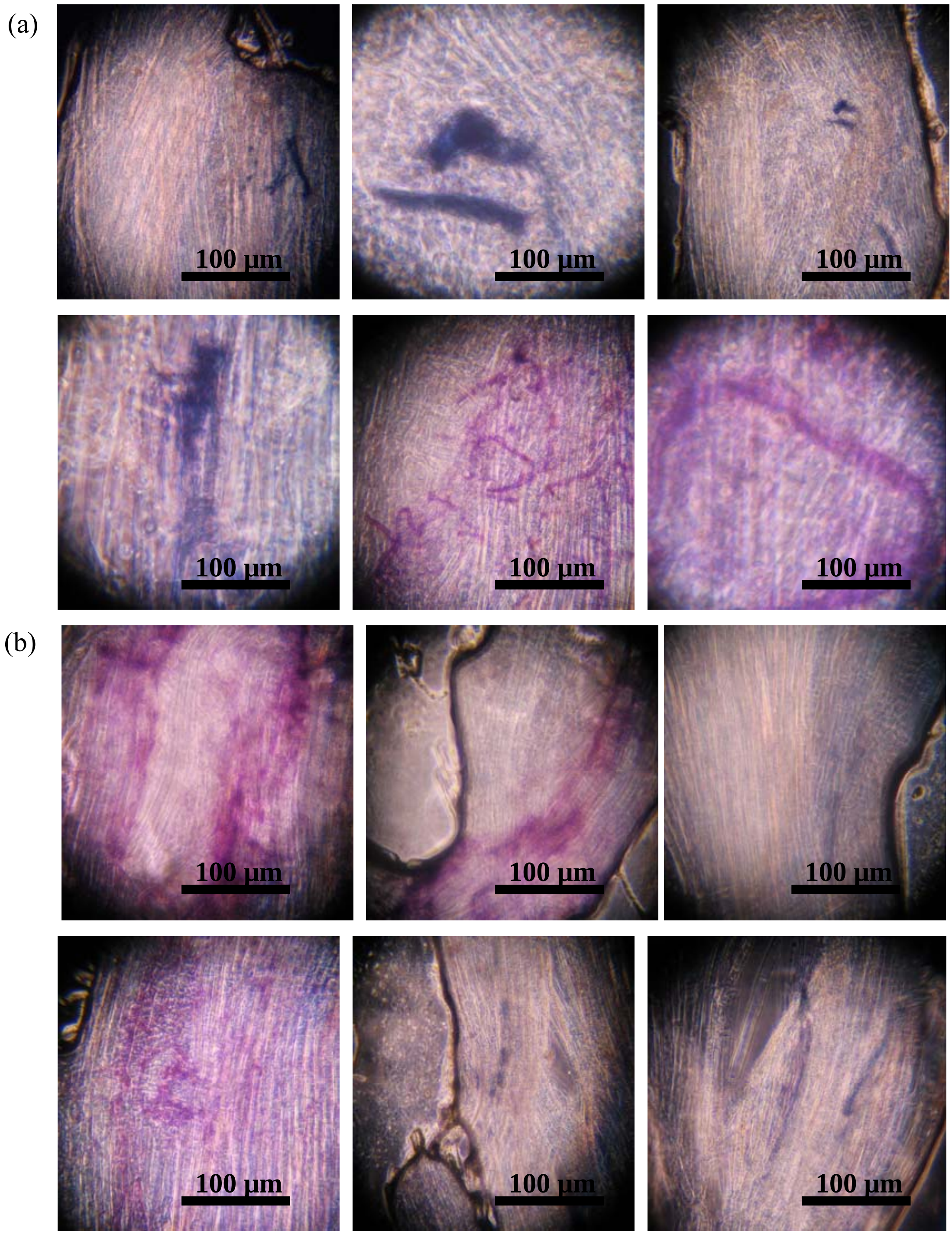


Figure 8 Feature of arbuscules of T_2I_2 (60 kg P_2O_5 ha^{-1}, inoculated *Glomus*) for Crop 1 (a) and Crop 2 (b).

CONCLUSION AND RECOMMENDATION

Conclusion

From the experimental results, the conclusion can be drawn as follows:

1. AM fungi inoculation and P fertilizer had a significant effect on shoot height, shoot circumference, fresh weight, dry weight and shoot nitrogen concentration of baby corn (*Zea mays* L.) respectively. However this experiment did not show interactions between P fertilizer rate and AM fungi inoculation.

2. The most efficient amount of P_2O_5 of Crop 1 is at 60 kilogram per hectare, and inoculation had a highly significant effect ($p<0.01$) on shoot height, fresh weight, and it also had a significant effect ($p<0.05$) on dry weight (Table 6). So treatment T_2I_2 (60 kilogram P_2O_5 per hectare, inoculated *Glomus*) had the most effect on baby corn growth (Table 5).

Sustainable food production in the Tropics is often severely constrained by the fragility of soils, being prone to several forms of degradation (Irene and Thomas 2006). Making better use of the biological resources in these soils can contribute to enhanced sustainability. Mycorrhizal fungi constitute an important role in this respect.

3. For Crop 2, the most efficient amount of P_2O_5 is at 60 kilogram per hectare, and inoculation did not have a significant effect on shoot height, shoot circumference, fresh weight, or dry weight. Treatment T_2I_1 (60 kilogram P_2O_5 per hectare, not inoculated *Glomus*) had the most effect on baby corn growth (Table 5). Even though the experiment field of Crop 1 and Crop 2 adjoined, some results were different. Not only P fertilizer and AM fungi inoculation, but also the other bias, such as variable soil moisture condition could affect the plant growth.

In case of Crop 2, not inoculated AM fungi was more effective than inoculated AM fungi. This result would show that such soil cultivation management would be more effective than AM fungi inoculation to optimize the economics of crop production.

4. There was no significant interaction between P fertilizer rate and AM fungi inoculation on nutrient (nitrogen, phosphorus and potassium) concentration of the shoot of baby corn (*Zea mays* L.) in this experiment for both Crop 1 and Crop 2. Treatment T_2I_2 had effect on root colonization on every replication (Table 7). In general, AM fungi promote plant growth and nutrient concentration of low fertility soils (Smith and Gianinazzi-Pearson, 1988; Marschner, 1995), and AM fungi can help increase the effectiveness of P fertilizer added to soils that are P-deficient or have high P-fixing capacity. For example, in an acidic soil, addition of AM fungi and rock phosphate fertilizer together were more effective in enhancing the growth of corn than when rock phosphate was added alone (Alloush and Clark, 2001). Though treatment I_1 was not inoculated AM fungi, there were some arbuscules (Figure 7). It would be that native AM fungi also could work. When density of native AM fungi is low and the effectiveness of it is high, improvement density of native AM fungi is more effective than inoculation. And due to sufficient rate of P fertilizer in both Crop 1 and Crop 2, there was no significant interaction on nutrient concentration. In general, nutrient uptake is likely to be affected by P deficiency (Karen, 1984), nitrogen and pottasium uptake can be influenced by both soil P level and mycorrhizal inoculation.

5. AM fungi contribution to physical, chemical and biological soil quality has been acknowledged, and therefore more fundamental and strategic studies in the field are needed. With such studies, the policy to support improvement of soil fertility may be less based on increasing nutrients input through fertilizer programs (Scoones and Toulmin, 1998) and more on management of local biodiversity. And such studies might prove that mycorrhizal fungi could be the most important untapped understood resource (Sanginga *et al*., 1999) for nutrient uptake and plant growth in agriculture.

Recommendation

For further study, comparing the effects of native AM fungi and inoculated AM fungi should be tested under field experiment. To examine the effect of P fertilizer under lower fertility, T_2, T_3 and T_4 rate should be changed from 60, 120 and 240 kilograms P_2O_5 per hectare to 30, 60 and 90 kilograms P_2O_5 per hectare, respectively. And to close the gap of fertilizer rate between T_3 and T_4, T_4 rate should be 1.5 time of T_3.

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APPENDIX

Appendix Table 1 Shoot height, circumference, fresh weight, dry weight and P content of baby corn (*Zea mays* L.) at four P rates for Crop 1.

P_2O_5 (kg ha^{-1})	AMF	Rep	Height (cm)	Shoot circum-ference (cm)	Fresh weight (g)	Dry weight (g)	P concentration (mg plant^{-1})
0 (T_1)	I_1	1	40.68	3.03	1000	108.53	40.55
		2	6.25	0.65	250	203.07	78.78
		3	16.63	1.62	410	78.47	21.72
		4	16.21	1.74	400	100.91	36.35
		Mean	**19.94**	**1.76**	**515**	**122.75**	**44.35**
	I_2	1	28.49	2.23	980	134.8	57.19
		2	36.29	2.60	750	153.63	61.03
		3	20.56	2.23	605	165.25	48.81
		4	4.19	0.81	90	99	37.49
		Mean	**22.38**	**1.97**	**606.25**	**138.17**	**51.13**
60 (T_2)	I_1	1	26.01	2.11	750	331.2	116.31
		2	53.08	2.75	1039	230.29	83.28
		3	31.88	3.08	1000	298.65	124.02
		4	2.21	0.34	22.6	75.63	25.84
		Mean	**28.29**	**2.07**	**702.9**	**233.94**	**87.36**
	I_2	1	69.03	3.26	1550	360.8	119.93
		2	72.90	3.57	1800	429.95	151.14
		3	29.92	2.44	700	187.33	48.39
		4	42.54	2.59	1305	326.98	115.10
		Mean	**53.60**	**2.97**	**338.8**	**326.27**	**108.64**
120 (T_3)	I_1	1	64.48	3.38	1500	338.23	134.27
		2	27.42	2.16	950	222.2	92.38
		3	20.41	2.33	550	110.47	35.70
		4	16.53	1.83	360	90.4	29.21
		Mean	**32.21**	**2.43**	**840**	**190.33**	**72.89**
	I_2	1	74.32	3.22	1550	408.14	127.75
		2	46.50	2.73	1390	194.82	89.13
		3	45.75	3.27	1250	276.93	84.36
		4	54.94	3.10	1350	313.14	112.84
		Mean	**55.38**	**3.08**	**1385**	**298.26**	**103.52**
240 (T_4)	I_1	1	55.90	3.08	1380	246.55	89.16
		2	34.33	2.48	800	186.93	72.52
		3	27.88	2.68	830	233.01	90.40
		4	8.98	1.35	230	65.08	27.06
		Mean	**31.77**	**2.40**	**810**	**182.89**	**69.78**
	I_2	1	55.59	3.50	1500	291.16	104.87
		2	29.92	2.23	800	120.94	43.56
		3	26.03	2.79	790	181.53	68.75
		4	49.06	3.15	1310	326.02	131.11
		Mean	**40.15**	**2.92**	**1100**	**229.91**	**87.07**

Appendix Table 2 Shoot height, circumference, fresh weight, dry weight and P content of baby corn (*Zea mays* L.) at four P rates for Crop 2.

P_2O_5 (kg ha^{-1})	AMF	Rep	Height (cm)	Shoot Circum-ference (cm)	Fresh weight (g)	Dry weight (g)	P content (mg $plant^{-1}$)
0 (T_1)	I_1	1	14.92	1.80	445	157.20	40.61
		2	23.46	1.82	500	219.03	54.55
		3	32.23	2.79	900	208.22	42.22
		4	12.40	1.57	450	90.70	18.39
		Mean	**20.75**	**1.99**	**573.75**	**168.79**	**38.94**
	I_2	1	32.67	2.38	810	362.66	83.61
		2	10.15	1.07	200	150.90	37.59
		3	31.13	2.72	720	164.67	31.87
		4	8.25	1.09	170	120.51	36.71
		Mean	**20.55**	**1.81**	**475**	**199.69**	**47.44**
60 (T_2)	I_1	1	41.29	2.26	840	81.53	22.57
		2	15.96	1.34	220	108.93	24.11
		3	52.59	2.95	1000	270.35	74.85
		4	25.90	2.48	780	158.71	42.47
		Mean	**33.94**	**2.26**	**710**	**154.88**	**41.00**
	I_2	1	21.29	1.68	680	179.03	49.56
		2	27.88	1.90	570	185.10	40.96
		3	53.51	2.91	1150	304.30	90.08
		4	17.06	1.63	580	126.49	27.99
		Mean	**29.93**	**2.03**	**745**	**198.73**	**52.15**
120 (T_3)	I_1	1	44.63	2.57	1030	249.18	68.99
		2	30.17	2.89	760	236.31	87.30
		3	31.08	2.85	800	179.17	41.31
		4	13.88	1.55	600	183.01	43.89
		Mean	**29.94**	**2.47**	**797.5**	**211.92**	**60.37**
	I_2	1	47.67	2.71	1060	283.63	91.65
		2	32.73	2.13	570	192.41	46.14
		3	31.25	2.50	720	176.88	50.66
		4	28.50	2.23	720	80.20	22.20
		Mean	**35.04**	**2.39**	**767.5**	**183.28**	**52.67**
240 (T_4)	I_1	1	25.88	1.90	620	222.89	78.22
		2	27.63	2.10	710	188.34	52.14
		3	48.57	2.96	1050	231.72	64.15
		4	27.94	1.96	590	152.31	63.32
		Mean	**32.50**	**2.23**	**742.5**	**198.82**	**64.46**
	I_2	1	45.10	2.27	1060	349.77	128.06
		2	43.75	2.26	930	243.80	78.78
		3	25.95	2.73	640	176.14	66.70
		4	63.85	3.05	1470	375.63	100.79
		Mean	**44.66**	**2.58**	**1025**	**286.34**	**93.58**

Appendix Table 3 Shoot circumference of all baby corn (*Zea mays* L.) for Crop 1.

P_2O_5 (kg ha^{-1})	AMF	Rep 1 Crop no.	Sc[1/] (cm)	Rep 2 Crop no.	sc (cm)	Rep 3 Crop no.	sc (cm)	Rep 4 Crop no.	sc (cm)
		1	4.5	1	3.8	1	2.5	1	2.0
		2	2.8	2	4.0	2	3.2	2	2.5
		3	3.1	3	0	3	3.0	3	0
		4	3.2	4	0	4	2.7	4	2.0
		5	3.1	5	0	5	2.5	5	1.5
		6	3.6	6	0	6	3.0	6	0
		7	2.9	7	0	7	3.2	7	2.5
		8	3.5	8	0	8	0	8	2.5
		9	2.7	9	0	9	0	9	3.0
		10	3.2	10	0	10	0	10	2.2
		11	4.8	11	0	11	0	11	2.2
		12	4.1	12	0	12	0	12	3.5
	I_1	13	3.1	13	4.3	13	3.5	13	1.7
		14	3.6	14	3.5	14	2.7	14	0
		15	3.2	15	0	15	3.2	15	0
		16	2.1	16	0	16	2.7	16	2
		17	3.1	17	0	17	2.7	17	0
		18	3.2	18	0	18	2.0	18	0
		19	0	19	0	19	2.0	19	2.7
		20	3.4	20	0	20	0	20	2.7
		21	3.3	21	0	21	0	21	0
		22	3.0	22	0	22	0	22	3.5
		23	3.1	23	0	23	0	23	2.5
		24	0	24	0	24	0	24	2.7
0		**Mean**	**3.0**	**Mean**	0.7	**Mean**	1.6	**Mean**	1.7
(T_1)									
		1	2.7	1	2.0	1	4.0	1	2.0
		2	0	2	0	2	3.3	2	2.6
		3	0	3	0	3	3.0	3	2.3
		4	3.5	4	2.5	4	3.5	4	3.0
		5	0	5	0	5	3.0	5	2.7
		6	3.0	6	2.8	6	3.1	6	2.2
		7	3.2	7	0	7	3.7	7	0
		8	3.3	8	3.7	8	7.8	8	0
		9	4.4	9	2.5	9	0	9	0
		10	3.2	10	3.8	10	0	10	0
		11	2.6	11	2.4	11	0	11	0
		12	4.4	12	3.4	12	0	12	0
	I_2	13	2.0	13	3.2	13	2.5	13	2.0
		14	0	14	3.0	14	2.0	14	2.6
		15	0	15	2.0	15	3.6	15	0
		16	2.5	16	2.5	16	3.8	16	0
		17	0	17	2.9	17	3.8	17	0
		18	2.8	18	3.0	18	3.5	18	0
		19	0	19	3.2	19	3	19	0
		20	3.7	20	2.5	20	0	20	0
		21	2.5	21	2.4	21	0	21	0
		22	3.8	22	3.0	22	0	22	0
		23	2.4	23	2.2	23	0	23	0
		24	3.4	24	0	24	0	24	0
		Mean	**2.2**	**Mean**	**2.2**	**Mean**	**2.2**	**Mean**	**0.8**

Appendix Table 3 (Continued)

P_2O_5 (kg ha^{-1})	AMF	Rep 1 Crop no.	Sc[1/] (cm)	Rep 2 Crop no.	sc (cm)	Rep 3 Crop no.	sc (cm)	Rep 4 Crop no.	sc (cm)
		1	3.8	1	4.5	1	3.9	1	0
		2	0	2	3.9	2	3.5	2	0
		3	3.3	3	3.5	3	3.9	3	3.0
		4	0	4	3.8	4	2.4	4	1.8
		5	4.5	5	3.4	5	2.0	5	1.2
		6	2.4	6	3.5	6	3.0	6	0
		7	2.6	7	2.5	7	2.5	7	2.2
		8	2.8	8	2.5	8	3.3	8	0
		9	2.5	9	3.0	9	4.0	9	0
		10	3.2	10	3.0	10	2.9	10	0
		11	4.0	11	3.0	11	3.0	11	0
		12	3.6	12	2.8	12	2.5	12	0
	I_1	13	3.1	13	3.0	13	3.0	13	0
		14	0	14	0	14	3.0	14	0
		15	3.1	15	4.0	15	3.0	15	0
		16	0	16	3.0	16	3.8	16	0
		17	2.2	17	2.3	17	3.0	17	0
		18	0	18	3.4	18	2.3	18	0
		19	0	19	0	19	2.8	19	0
		20	0	20	3.2	20	2.9	20	0
		21	3.0	21	1.5	21	3.6	21	0
		22	3.3	22	2.8	22	3.5	22	0
		23	3.3	23	3.5	23	3.7	23	0
		24	0	24	0	24	2.4	24	0
60 (T_2)		**Mean**	**2.1**	**Mean**	**2.8**	**Mean**	**3.1**	**Mean**	**0.3**
		1	3.3	1	5.0	1	3.5	1	3.7
		2	3.4	2	5.0	2	3.0	2	0
		3	3.3	3	2.5	3	3.0	3	3.4
		4	3.4	4	4.1	4	2.2	4	3.5
		5	2.8	5	3.1	5	2.3	5	3.7
		6	4.2	6	3.0	6	3.5	6	3.5
		7	4.4	7	3.5	7	2.0	7	0
		8	2.9	8	3.0	8	2.0	8	3.0
		9	3.8	9	4.0	9	1.8	9	4.2
		10	3.4	10	5.5	10	3.0	10	4.2
		11	3.3	11	4.5	11	3.0	11	3.5
		12	3.8	12	5.2	12	0	12	2.5
	I_2	13	3.6	13	4.5	13	3.0	13	0
		14	3.4	14	0	14	3.1	14	0
		15	3.6	15	4.6	15	3.3	15	3.5
		16	3.2	16	3.0	16	2.6	16	3.5
		17	3.8	17	2.0	17	3.0	17	2.5
		18	2.3	18	3.0	18	3.5	18	3.7
		19	0	19	3.5	19	2.4	19	0
		20	3.1	20	2.5	20	2.8	20	0
		21	3.5	21	4.0	21	2.7	21	1.8
		22	3.2	22	6.0	22	2.8	22	4.8
		23	2.8	23	4.2	23	0	23	2.5
		24	3.8	24	0	24	0	24	4.7
		Mean	**3.3**	**Mean**	**3.6**	**Mean**	**2.4**	**Mean**	**2.6**

Appendix Table 3 (Continued)

P_2O_5 (kg ha^{-1})	AMF	Rep 1 Crop no.	Sc[1/] (cm)	Rep 2 Crop no.	sc (cm)	Rep 3 Crop no.	sc (cm)	Rep 4 Crop no.	sc (cm)
		1	3.2	1	4.2	1	3.0	1	3.6
		2	3.3	2	3.7	2	2.2	2	3.0
		3	2.8	3	3.8	3	3.2	3	2.6
		4	3.6	4	3.5	4	0	4	2.4
		5	3.4	5	4.5	5	0	5	0
		6	3.5	6	3.0	6	2	6	2.7
		7	3.7	7	3.3	7	1.8	7	2.0
		8	4.7	8	0	8	3.7	8	2.5
		9	3.6	9	0	9	3.0	9	2.6
		10	3.5	10	0	10	0	10	2.5
		11	3.1	11	0	11	3.2	11	2.7
		12	3.4	12	0	12	0	12	2.4
	I_1	13	4.3	13	3.6	13	2.7	13	0
		14	3.3	14	3.7	14	4.3	14	0
		15	3.1	15	3.9	15	3.6	15	0
		16	3.7	16	3.3	16	4.8	16	3.2
		17	3.0	17	4.7	17	0	17	0
		18	0	18	2.9	18	4.0	18	2.1
		19	3.8	19	3.8	19	2.0	19	2.1
		20	2.8	20	0	20	2.5	20	2.8
		21	3.6	21	0	21	2.5	21	2.2
		22	3.6	22	0	22	4.0	22	2.5
		23	3.4	23	0	23	3.5	23	0
		24	4.8	24	0	24	0	24	0
120 (T_3)		**Mean**	**3.4**	**Mean**	**2.2**	**Mean**	**2.3**	**Mean**	**1.8**
		1	3.0	1	3.4	1	3.0	1	3.0
		2	2.4	2	2.8	2	2.9	2	2.5
		3	4.1	3	3.2	3	2.9	3	2.5
		4	3.1	4	3.0	4	2.8	4	3.2
		5	3.5	5	3.2	5	3.2	5	3.2
		6	4.2	6	3.6	6	3.2	6	3.5
		7	3.5	7	3.5	7	3.4	7	3.7
		8	3.6	8	3	8	3.9	8	3.2
		9	3.7	9	3.1	9	3.5	9	2.0
		10	3.1	10	4.3	10	4.2	10	4.0
		11	3.8	11	0	11	2.5	11	3.2
		12	3.4	12	0	12	3.7	12	3.8
	I_2	13	3.0	13	3.0	13	4.5	13	4.8
		14	2.4	14	2.5	14	3.1	14	3.8
		15	4.1	15	4.0	15	3.3	15	3.0
		16	3.1	16	2.8	16	3.2	16	3.8
		17	3.5	17	3.3	17	3.2	17	3.7
		18	4.2	18	3.5	18	3.2	18	0
		19	3.5	19	2.6	19	3.1	19	3.5
		20	3.6	20	3.5	20	4.3	20	3.2
		21	3.7	21	3.3	21	2.6	21	2.8
		22	3.1	22	4.0	22	4.4	22	2.8
		23	3.8	23	0	23	2.4	23	3.0
		24	3.4	24	0	24	2.0	24	2.3
		Mean	**3.5**	**Mean**	**2.7**	**Mean**	**3.3**	**Mean**	**3.1**

Appendix Table 3 (Continued)

P_2O_5 (kg ha^{-1})	AMF	Rep 1 Crop no.	$Sc^{1/}$ (cm)	Rep 2 Crop no.	sc (cm)	Rep 3 Crop no.	sc (cm)	Rep 4 Crop no.	sc (cm)
		1	2.2	1	3.9	1	3.2	1	2.5
		2	3.0	2	2.5	2	2.2	2	2.2
		3	3.6	3	2.5	3	3.3	3	2.3
		4	3.4	4	3.0	4	2.5	4	3.4
		5	2.0	5	3.3	5	2.8	5	3.4
		6	4.3	6	2.3	6	3.8	6	0
		7	2.2	7	1.7	7	2.1	7	3.3
		8	2.9	8	3.6	8	3.0	8	3
		9	2.0	9	2.0	9	2.5	9	0
		10	3.4	10	3.8	10	2.2	10	0
		11	2.6	11	2.2	11	3.2	11	0
		12	4.2	12	2.6	12	0	12	2.4
	I_1	13	3.4	13	0	13	2.1	13	1.7
		14	2.3	14	1.5	14	3.1	14	2.6
		15	3.2	15	2.0	15	2.9	15	2.5
		16	3.1	16	0	16	3.5	16	3.2
		17	4.0	17	2.0	17	3.1	17	0
		18	3.5	18	4.0	18	3.2	18	0
		19	3.3	19	3.5	19	4.5	19	0
		20	2.7	20	3.6	20	3.8	20	0
		21	3.1	21	3.0	21	2.0	21	0
		22	4.3	22	2.3	22	2.0	22	0
		23	2.0	23	2.2	23	3.3	23	0
		24	3.2	24	2.1	24	0	24	0
240 (T_4)		**Mean**	**3.1**	**Mean**	**2.5**	**Mean**	**2.7**	**Mean**	**1.4**
		1	4.3	1	2.9	1	2.3	1	3.0
		2	3.5	2	3.5	2	3.2	2	3.2
		3	3.2	3	1.9	3	3.7	3	5.0
		4	4.1	4	3.6	4	4.5	4	3.5
		5	3.0	5	1.8	5	3.5	5	4.0
		6	3.7	6	2.1	6	4.2	6	4.0
		7	3.9	7	2.9	7	3.5	7	1.7
		8	3.5	8	2.7	8	3.8	8	2.5
		9	2.9	9	2.4	9	3.2	9	3.2
		10	1.9	10	3.4	10	1.4	10	3.0
		11	3.1	11	0	11	0	11	4.0
		12	4.6	12	0	12	0	12	3.2
	I_2	13	3.4	13	3.2	13	3.3	13	3.2
		14	3.9	14	2.8	14	2.8	14	3.5
		15	3.2	15	3.1	15	4.1	15	4.0
		16	3.5	16	1.8	16	2.8	16	0
		17	3.0	17	3.8	17	3.7	17	4.2
		18	3.8	18	2.9	18	3.0	18	0
		19	4.0	19	2.2	19	3.3	19	2.5
		20	3.4	20	3.1	20	3.5	20	3.5
		21	3.6	21	3.3	21	2.7	21	3.2
		22	4.0	22	0	22	4.4	22	3.2
		23	3.1	23	0	23	0	23	4.5
		24	3.5	24	0	24	0	24	3.5
		Mean	**3.5**	**Mean**	**2.2**	**Mean**	**2.8**	**Mean**	**3.2**

[1/]sc = shoot circumference (cm)

Appendix Table 4 Shoot circumference of all baby corn (*Zea mays L.*) for Crop 2.

P_2O_5 (kg ha^{-1})	AMF	Rep 1 Crop no.	Rep 1 Sc[1/] (cm)	Rep 2 Crop no.	Rep 2 sc (cm)	Rep 3 Crop no.	Rep 3 sc (cm)	Rep 4 Crop no.	Rep 4 sc (cm)
		1	2.8	1	2.6	1	4.0	1	3.5
		2	2.7	2	3.2	2	0	2	2.7
		3	3.0	3	3.0	3	3.1	3	3.5
		4	3.4	4	3.2	4	3.5	4	3.0
		5	2.4	5	1.6	5	3.0	5	3.4
		6	3.0	6	2.8	6	3.7	6	0
		7	3.7	7	2.8	7	2.6	7	3.4
		8	0	8	2.9	8	3.7	8	3.5
		9	0	9	0	9	3.2	9	3.2
		10	0	10	0	10	3.0	10	0
		11	0	11	0	11	2.5	11	0
		12	0	12	0	12	2.7	12	2.7
	I_1	13	3.5	13	2.4	13	3.4	13	2.4
		14	3.3	14	1.7	14	0	14	0
		15	3.5	15	2.8	15	4.0	15	0
		16	2.7	16	2.5	16	3.1	16	0
		17	2.2	17	3.5	17	3.2	17	0
		18	3.7	18	2.8	18	3.5	18	0
		19	3.2	19	3.0	19	3.0	19	4.2
		20	0	20	2.8	20	4.2	20	0
		21	0	21	0	21	0	21	0
		22	0	22	0	22	0	22	0
		23	0	23	0	23	3.5	23	0
		24	0	24	0	24	4.0	24	2.2
0 (T_1)		**Mean**	**1.8**	**Mean**	**1.8**	**Mean**	**2.8**	**Mean**	**1.6**
		1	2.5	1	2.7	1	2.2	1	2.0
		2	3.5	2	3.0	2	1.7	2	2.4
		3	3.3	3	2.8	3	2.5	3	3.1
		4	3.0	4	2.8	4	1.5	4	2.3
		5	2.6	5	2.8	5	2.6	5	1.8
		6	2.8	6	2.0	6	3	6	2.2
		7	2.8	7	3.0	7	3.7	7	2.1
		8	4.0	8	2.2	8	3.3	8	0
		9	1.9	9	2.2	9	2.8	9	0
		10	3.5	10	1.8	10	3.2	10	1.9
		11	2.0	11	0	11	3.2	11	0
		12	0	12	0	12	2.3	12	0
	I_2	13	2.7	13	2.3	13	0	13	0
		14	3.0	14	2.8	14	2.5	14	0
		15	2.8	15	2.5	15	2.9	15	0
		16	2.8	16	2.9	16	2.9	16	2.8
		17	2.8	17	2.4	17	3.2	17	2.9
		18	2.0	18	0	18	4.2	18	2.7
		19	3.0	19	0	19	3.1	19	0
		20	2.2	20	0	20	2.8	20	0
		21	2.2	21	0	21	3.4	21	0
		22	1.8	22	0	22	3	22	0
		23	0	23	0	23	2.7	23	0
		24	0	24	0	24	2.5	24	0
		Mean	**2.4**	**Mean**	**1.6**	**Mean**	**2.7**	**Mean**	**1.1**

Appendix Table 4 (Continued)

P_2O_5 (kg ha^{-1})	AMF	Rep 1 Crop no.	Sc[1/] (cm)	Rep 2 Crop no.	sc (cm)	Rep 3 Crop no.	sc (cm)	Rep 4 Crop no.	sc (cm)
		1	1.7	1	1.8	1	2.5	1	2.7
		2	3.1	2	2.3	2	2.2	2	3.2
		3	1.9	3	1.9	3	3.0	3	2.9
		4	3.2	4	2.3	4	2.5	4	3.6
		5	2.6	5	3.1	5	2.9	5	2.4
		6	2.7	6	1.8	6	3.5	6	3.6
		7	2.2	7	1.7	7	2.2	7	3.2
		8	3.0	8	1.7	8	2.4	8	2.7
		9	1.7	9	0	9	3.2	9	2.7
		10	2.4	10	0	10	3.6	10	4.0
		11	2.5	11	0	11	3.2	11	3.2
		12	0	12	0	12	3.8	12	2.8
	I_1	13	2.8	13	1.8	13	3.0	13	3.2
		14	2.5	14	1.3	14	2.5	14	2.5
		15	3.2	15	2.2	15	0	15	0
		16	2.7	16	3.0	16	3.0	16	0
		17	2.3	17	2.2	17	3.0	17	3.6
		18	2.7	18	2.2	18	3.5	18	0
		19	2.0	19	2.9	19	3.5	19	2.0
		20	3.3	20	0	20	3.1	20	2.6
		21	3.2	21	0	21	3.5	21	0
		22	1.5	22	0	22	3.3	22	2.4
		23	1.0	23	0	23	4.0	23	3.0
		24	0	24	0	24	3.3	24	3.2
60		**Mean**	**2.3**	**Mean**	**1.3**	**Mean**	**2.9**	**Mean**	**2.5**
(T_2)									
		1	3.0	1	2.1	1	3.0	1	3.0
		2	3.7	2	2.9	2	2.5	2	0
		3	2.4	3	2.4	3	3.4	3	4.5
		4	3.2	4	2.0	4	3.1	4	3.2
		5	2.8	5	3.5	5	2.3	5	2.8
		6	3.3	6	3.0	6	2.8	6	0
		7	3.0	7	3.0	7	3.2	7	0
		8	0	8	2.5	8	2.5	8	3.5
		9	0	9	3.0	9	2.5	9	2.7
		10	0	10	0	10	4.2	10	2.1
		11	0	11	0	11	3.2	11	0
		12	0	12	0	12	3.3	12	2.1
	I_2	13	2.7	13	1.8	13	2.8	13	3.0
		14	3.4	14	2.2	14	3.5	14	0
		15	3.1	15	1.8	15	3.0	15	3.0
		16	2.9	16	3.4	16	2.5	16	0
		17	2.7	17	2.6	17	2.2	17	3.0
		18	2.2	18	2.5	18	3.2	18	0
		19	1.9	19	2.5	19	2.7	19	0
		20	0	20	2.5	20	3.6	20	3.2
		21	0	21	1.9	21	3.3	21	0
		22	0	22	0	22	3.2	22	0
		23	0	23	0	23	3.8	23	0
		24	0	24	0	24	0	24	3.0
		Mean	**1.7**	**Mean**	**1.9**	**Mean**	**2.9**	**Mean**	**1.6**

Appendix Table 4 (Continued)

P_2O_5 (kg ha^{-1})	AMF	Rep 1 Crop no.	Sc[1/] (cm)	Rep 2 Crop no.	sc (cm)	Rep 3 Crop no.	sc (cm)	Rep 4 Crop no.	sc (cm)
		1	2.8	1	2.6	1	3.0	1	0
		2	3.2	2	2.4	2	2.8	2	3.8
		3	3.3	3	4.1	3	4.5	3	2.5
		4	2.4	4	2.8	4	3.0	4	0
		5	3.1	5	3.5	5	2.0	5	1.2
		6	1.8	6	3.1	6	3.0	6	2.0
		7	2.9	7	3.0	7	3.0	7	0
		8	3.8	8	2.5	8	2.5	8	2.6
		9	3.3	9	3.3	9	2.5	9	3.7
		10	3.3	10	2.0	10	3.5	10	0
		11	1.9	11	2.6	11	2.4	11	3.2
		12	0	12	3.5	12	2.7	12	2.7
	I_1	13	3.5	13	2.8	13	0	13	0
		14	3.3	14	3.0	14	3.0	14	2.0
		15	2.2	15	3.5	15	0	15	0
		16	2.5	16	3.5	16	3.5	16	0
		17	3.0	17	4.4	17	4.0	17	2.3
		18	1.6	18	3.0	18	4.5	18	2.7
		19	2.7	19	2.8	19	3.1	19	0
		20	2.5	20	3.2	20	4.0	20	3.5
		21	4.1	21	2.6	21	2.5	21	2.4
		22	3.2	22	2.7	22	3.0	22	0
		23	1.3	23	2.5	23	3.0	23	2.5
		24	0	24	0	24	3.0	24	0
120		**Mean**	**2.6**	**Mean**	**2.9**	**Mean**	**2.9**	**Mean**	**1.5**
(T_3)									
		1	2.8	1	2.8	1	3.5	1	3.0
		2	2.6	2	2.6	2	3.5	2	3.0
		3	3.0	3	3.0	3	2.8	3	2.6
		4	3.2	4	3.2	4	2.0	4	0
		5	3.3	5	3.3	5	3.2	5	2.9
		6	2.2	6	2.2	6	1.8	6	3.4
		7	2.4	7	2.4	7	3.1	7	3.2
		8	2.2	8	2.2	8	2.5	8	3.0
		9	4.1	9	4.1	9	3.2	9	3.1
		10	3.2	10	3.2	10	3.2	10	2.6
		11	2.7	11	2.7	11	2.3	11	2.8
		12	1.6	12	1.6	12	3.0	12	3.4
	I_2	13	3.5	13	3.5	13	3.0	13	0
		14	2.5	14	2.5	14	0	14	3.1
		15	2.7	15	2.7	15	0	15	2.6
		16	3.1	16	3.1	16	4.0	16	0
		17	3.2	17	3.2	17	0	17	3.9
		18	3.0	18	3.0	18	2.1	18	0
		19	2.2	19	2.2	19	4.2	19	0
		20	3.3	20	3.3	20	2.0	20	2.7
		21	2.5	21	2.5	21	3.3	21	2.5
		22	2.2	22	2.2	22	2.6	22	3.0
		23	3.5	23	3.5	23	2.5	23	0
		24	0	24	0	24	2.3	24	2.8
		Mean	**2.7**	**Mean**	**2.7**	**Mean**	**2.5**	**Mean**	**2.2**

Appendix Table 4 (Continued)

P_2O_5 (kg ha^{-1})	AMF	Rep 1 Crop no.	Sc[1/] (cm)	Rep 2 Crop no.	sc (cm)	Rep 3 Crop no.	sc (cm)	Rep 4 Crop no.	sc (cm)
		1	2.5	1	3.0	1	2.7	1	3.9
		2	2.1	2	3.2	2	3.8	2	0
		3	2.3	3	2.7	3	2.8	3	3.0
		4	3.0	4	2.4	4	3.1	4	1.5
		5	1.3	5	2.8	5	2.8	5	2.7
		6	2.6	6	3.6	6	2.3	6	2.5
		7	3.2	7	3.0	7	3.2	7	2.0
		8	2.9	8	4.2	8	2.6	8	0
		9	2.0	9	3.5	9	3.2	9	3.0
		10	1.8	10	0	10	2.7	10	2.0
		11	0	11	0	11	3.2	11	2.9
		12	0	12	0	12	3.0	12	2.5
	I_1	13	2.4	13	3.1	13	3.2	13	0
		14	2.6	14	2.6	14	3.2	14	0
		15	2.2	15	2.7	15	3.4	15	2.2
		16	1.6	16	3.5	16	4.2	16	2.6
		17	2.5	17	1.9	17	2.5	17	2.9
		18	2.0	18	2.0	18	3.0	18	2.3
		19	2.4	19	2.7	19	3.5	19	0
		20	2.4	20	3.5	20	3.4	20	0
		21	3.7	21	0	21	3.6	21	3.1
		22	0	22	0	22	3.0	22	2.0
		23	0	23	0	23	2.6	23	2.4
		24	0	24	0	24	0	24	3.5
240 (T_4)		**Mean**	**1.9**	**Mean**	**2.1**	**Mean**	**3.0**	**Mean**	**2.0**
		1	1.9	1	3.2	1	2.7	1	3.0
		2	3.7	2	2.1	2	2.7	2	3.3
		3	2.2	3	2.5	3	2.7	3	3.9
		4	2.5	4	2.2	4	2.4	4	2.3
		5	3.0	5	1.8	5	2.4	5	2.7
		6	3.7	6	2.5	6	2.6	6	3.7
		7	3.2	7	3.7	7	3.7	7	2.7
		8	3.5	8	1.8	8	2.8	8	3.6
		9	5.2	9	2.7	9	3.0	9	2.7
		10	0	10	3.0	10	2.7	10	4.0
		11	0	11	0	11	3.5	11	4.0
		12	0	12	0	12	2.5	12	3.5
	I_2	13	2.8	13	2.8	13	2.5	13	2.6
		14	2.4	14	3.3	14	2.9	14	2.5
		15	3.6	15	2.3	15	2.5	15	0
		16	3.6	16	4.0	16	2.8	16	3.1
		17	3.5	17	2.5	17	2.7	17	4.1
		18	1.5	18	2.6	18	2.9	18	2.6
		19	3.7	19	3.5	19	3.0	19	2.4
		20	4.4	20	1.9	20	2.9	20	3.7
		21	0	21	3.1	21	2.0	21	4.0
		22	0	22	2.8	22	2.4	22	2.7
		23	0	23	0	23	3.2	23	3.7
		24	0	24	0	24	1.9	24	2.5
		Mean	**2.3**	**Mean**	**2.3**	**Mean**	**2.7**	**Mean**	**3.1**

[1/]sc = shoot circumference (cm)

Appendix Table 5 Shoot height of all baby corn (*Zea mays* L.) for Crop 1.

P_2O_5 (kg ha^{-1})	AMF	Rep 1 Crop no.	Rep 1 sh [2/] (cm)	Rep 2 Crop no.	Rep 2 sh (cm)	Rep 3 Crop no.	Rep 3 sh (cm)	Rep 4 Crop no.	Rep 4 sh (cm)
		1	54.2	1	28.0	1	23.0	1	12.0
		2	14.0	2	23.0	2	37.0	2	20.0
		3	43.0	3	0	3	37.0	3	0
		4	46.0	4	0	4	19.0	4	20.0
		5	54.4	5	0	5	38.0	5	15.0
		6	80.4	6	0	6	38.0	6	0
		7	23.0	7	0	7	34.0	7	23.0
		8	56.0	8	0	8	0	8	20.0
		9	25.0	9	0	9	0	9	33.0
		10	41.8	10	0	10	0	10	20.0
		11	76.5	11	0	11	0	11	22.5
		12	28.3	12	0	12	0	12	60.0
	I_1	13	40.0	13	69.0	13	38.0	13	4.0
		14	55.1	14	30.0	14	21.0	14	0
		15	42.0	15	0	15	30.0	15	0
		16	24.5	16	0	16	21.0	16	15.0
		17	38.2	17	0	17	36.0	17	0
		18	67.0	18	0	18	14.0	18	0
		19	0.0	19	0	19	13.0	19	22.0
		20	52.0	20	0	20	0	20	25.0
		21	30.5	21	0	21	0	21	0
		22	42.0	22	0	22	0	22	26.5
		23	42.3	23	0	23	0	23	25.5
		24	0.0	24	0	24	0	24	25.5
0		**Mean**	**40.7**	**Mean**	**6.3**	**Mean**	**16.6**	**Mean**	**16.2**
(T_1)									
		1	30.8	1	41.0	1	59.0	1	11.0
		2	0	2	74.0	2	23.0	2	16.5
		3	0	3	25.0	3	27.5	3	12.4
		4	46.2	4	41.0	4	39.0	4	14.3
		5	0	5	71.0	5	71.0	5	15.0
		6	49.8	6	54.0	6	28.0	6	12.4
		7	37.5	7	28.0	7	24.0	7	0
		8	43.3	8	27.0	8	13.5	8	0
		9	98.4	9	24.0	9	0	9	0
		10	44.3	10	34.0	10	0	10	0
		11	18.4	11	18.0	11	0	11	0
		12	64.4	12	0	12	0	12	0
	I_2	13	15.0	13	32.0	13	24.0	13	10.0
		14	0	14	39.0	14	9.5	14	9
		15	0	15	29.0	15	28.0	15	0
		16	14.0	16	48.0	16	28.0	16	0
		17	0	17	36.5	17	62.0	17	0
		18	30.7	18	57.0	18	25.0	18	0
		19	0	19	33.0	19	32.0	19	0
		20	38.8	20	16.5	20	0	20	0
		21	28.8	21	48.0	21	0	21	0
		22	59.2	22	57.0	22	0	22	0
		23	19.3	23	38.0	23	0	23	0
		24	44.9	24	0	24	0	24	0
		Mean	**28.5**	**Mean**	**36.3**	**Mean**	**20.6**	**Mean**	**4.2**

Appendix Table 5 (Continued)

P_2O_5 (kg ha^{-1})	AMF	Rep 1 Crop no.	Rep 1 sh [2/] (cm)	Rep 2 Crop no.	Rep 2 sh (cm)	Rep 3 Crop no.	Rep 3 sh (cm)	Rep 4 Crop no.	Rep 4 sh (cm)
		1	62.0	1	86.0	1	54.5	1	0
		2	0	2	65.0	2	54.0	2	0
		3	40.5	3	70.0	3	29.0	3	18.0
		4	0	4	78.5	4	15.0	4	12.0
		5	86.5	5	73.0	5	9.0	5	8.0
		6	29.4	6	62.0	6	31.0	6	0
		7	29.8	7	33.5	7	14.0	7	15.0
		8	15.0	8	30.0	8	30.0	8	0
		9	13.0	9	60.0	9	65.0	9	0
		10	30.3	10	70.0	10	25.0	10	0
		11	61.7	11	85.0	11	19.0	11	0
		12	38.5	12	58.5	12	15.0	12	0
	I_1	13	28.4	13	70.0	13	22.0	13	0
		14	0	14	0	14	52.5	14	0
		15	35.0	15	76.0	15	36.0	15	0
		16	0	16	49.0	16	21.0	16	0
		17	30.0	17	47.5	17	18.0	17	0
		18	0	18	61.5	18	19.0	18	0
		19	0	19	0	19	25.0	19	0
		20	0	20	34.5	20	30.0	20	0
		21	22.5	21	26.0	21	53.0	21	0
		22	41.2	22	48.0	22	53.0	22	0
		23	60.4	23	90.0	23	32.0	23	0
		24	0	24	0	24	43.0	24	0
60 (T_2)		**Mean**	**26.0**	**Mean**	**53.1**	**Mean**	**31.9**	**Mean**	**2.2**
		1	51.8	1	94.5	1	63.0	1	76.5
		2	74.9	2	110.0	2	48.0	2	0
		3	78.8	3	81.5	3	48.0	3	75.0
		4	82.0	4	92.5	4	14.0	4	44.0
		5	64.0	5	61.0	5	16.0	5	43.0
		6	98.3	6	78.0	6	72.0	6	30.0
		7	84.6	7	34.0	7	21.0	7	0
		8	58.5	8	62.0	8	18.0	8	45.0
		9	92.0	9	80.0	9	15.0	9	84.2
		10	74.4	10	77.0	10	19.0	10	96.5
		11	40.7	11	94.5	11	22.0	11	38.5
		12	86.8	12	102.5	12	0	12	40.0
	I_2	13	72.5	13	102.5	13	70.0	13	0
		14	73.4	14	0	14	41.0	14	0
		15	89.1	15	98.0	15	45.0	15	72.5
		16	84.5	16	92.0	16	26.0	16	53.5
		17	95.2	17	30.0	17	36.0	17	23.0
		18	27.0	18	77.0	18	64.0	18	77.7
		19	0	19	76.0	19	16.0	19	0
		20	58.5	20	54.0	20	19.0	20	0
		21	78.2	21	81.5	21	18.5	21	9.0
		22	59.8	22	80.0	22	26.5	22	92.0
		23	51.8	23	91.0	23	0	23	28.0
		24	80.0	24	0	24	0	24	92.5
		Mean	**69.0**	**Mean**	**72.9**	**Mean**	**29.9**	**Mean**	**42.5**

Appendix Table 5 (Continued)

P_2O_5 (kg ha^{-1})	AMF	Rep 1 Crop no.	sh [2/] (cm)	Rep 2 Crop no.	sh (cm)	Rep 3 Crop no.	sh (cm)	Rep 4 Crop no.	sh (cm)
		1	62.5	1	64.0	1	13.0	1	27.6
		2	55.4	2	43.0	2	14.0	2	21.8
		3	40.7	3	54.0	3	16.0	3	21.5
		4	66.8	4	34.0	4	0	4	15.0
		5	60.2	5	49.0	5	0	5	0
		6	77.8	6	16.0	6	10.0	6	21.9
		7	72.4	7	60.0	7	21.0	7	13.0
		8	83.0	8	0	8	22.0	8	30.0
		9	80.75	9	0	9	14.0	9	27.4
		10	83.3	10	0	10	0	10	31.9
		11	50.5	11	0	11	15.0	11	24.5
		12	72.3	12	0	12	0	12	20.0
	I_1	13	90.3	13	32.0	13	17.3	13	0
		14	79.9	14	62.0	14	66.5	14	0
		15	40.2	15	51.0	15	38.5	15	0
		16	72.3	16	54.0	16	57.5	16	33.5
		17	53.0	17	48.0	17	0	17	0
		18	0	18	33.0	18	30.0	18	15.0
		19	63.5	19	58.0	19	57.0	19	15.0
		20	39.5	20	0	20	20.0	20	30.0
		21	80.13	21	0	21	18.0	21	28.5
		22	51.8	22	0	22	35.0	22	20.0
		23	63.9	23	0	23	25.0	23	0
		24	107.4	24	0	24	0	24	0
120		**Mean**	**64.5**	**Mean**	**27.4**	**Mean**	**20.4**	**Mean**	**16.5**
(T_3)									
		1	66.3	1	32.0	1	46.0	1	55.5
		2	47.0	2	41.0	2	19.0	2	80.0
		3	118.5	3	34.0	3	49.0	3	43.5
		4	63.9	4	71.0	4	37.0	4	68.0
		5	95.0	5	34.0	5	62.0	5	67.1
		6	106.2	6	75.0	6	49.0	6	31.9
		7	52.4	7	46.0	7	35.0	7	82.0
		8	90.9	8	38.0	8	64.0	8	76.2
		9	83.4	9	57.0	9	53.0	9	17.7
		10	82.0	10	88.0	10	67.0	10	87.3
		11	76.9	11	0	11	15.0	11	42.0
		12	64.0	12	0	12	46.0	12	45.5
	I_2	13	69.2	13	35.0	13	66.0	13	87.7
		14	102.5	14	36.0	14	29.0	14	82.0
		15	115.2	15	76.0	15	42.0	15	41.8
		16	0	16	34.0	16	49.0	16	65.2
		17	102.4	17	73.0	17	60.0	17	33.5
		18	62.3	18	48.0	18	40.0	18	0
		19	92.3	19	36.0	19	38.0	19	53.2
		20	54.0	20	77.0	20	69.0	20	85.2
		21	55.6	21	82.0	21	58.0	21	47.5
		22	79.4	22	103.0	22	60.0	22	49.4
		23	0	23	0	23	23.0	23	38.0
		24	104.2	24	0	24	22.0	24	38.3
		Mean	**74.3**	**Mean**	**46.5**	**Mean**	**45.8**	**Mean**	**54.9**

Appendix Table 5 (Continued)

P_2O_5 (kg ha^{-1})	AMF	Rep 1 Crop no.	sh [2/] (cm)	Rep 2 Crop no.	sh (cm)	Rep 3 Crop no.	sh (cm)	Rep 4 Crop no.	sh (cm)
		1	21.8	1	53.0	1	15.0	1	21.5
		2	63.5	2	26.0	2	16.5	2	15.0
		3	48.4	3	34.0	3	28.0	3	15.0
		4	55.0	4	30.0	4	20.0	4	27.8
		5	29.0	5	44.0	5	22.0	5	24.2
		6	94.0	6	39.0	6	42.0	6	0
		7	22.4	7	20.0	7	15.0	7	18.4
		8	63.0	8	67.0	8	41.0	8	13.8
		9	40.7	9	20.0	9	51.5	9	0
		10	74.7	10	72.5	10	22.0	10	0
		11	47.0	11	22.0	11	28.0	11	0
		12	84.5	12	38.0	12	0	12	10.9
	I_1	13	72.0	13	0	13	7.0	13	16.5
		14	28.7	14	9.0	14	25.0	14	17.0
		15	33.7	15	31.0	15	38.0	15	18.8
		16	52.0	16	0	16	30.0	16	16.5
		17	83.0	17	27.0	17	45.0	17	0
		18	49.0	18	50.0	18	43.0	18	0
		19	70.9	19	42.0	19	35.0	19	0
		20	27.5	20	70.0	20	52.0	20	0
		21	82.5	21	47.5	21	42.0	21	0
		22	87.5	22	28.0	22	21.0	22	0
		23	35.2	23	24.0	23	30.0	23	0
		24	75.7	24	30.0	24	0	24	0
240 (T_4)		**Mean**	**55.9**	**Mean**	**34.3**	**Mean**	**27.9**	**Mean**	**9.0**
		1	73.7	1	39.0	1	19.0	1	29.0
		2	63.0	2	54.0	2	58.0	2	66.0
		3	47.0	3	35.0	3	23.0	3	99.0
		4	75.7	4	88.0	4	18.0	4	82.0
		5	49.0	5	16.0	5	33.0	5	89.0
		6	63.7	6	21.0	6	39.0	6	59.0
		7	54.7	7	18.0	7	40.0	7	15.0
		8	49.0	8	38.0	8	41.0	8	23.0
		9	27.5	9	16.0	9	30.0	9	35.5
		10	13.0	10	44.0	10	9.0	10	37.0
		11	30.0	11	0	11	0	11	83.0
		12	95.5	12	0	12	0	12	33.5
	I_2	13	56.7	13	59.0	13	37.0	13	44.0
		14	78.0	14	49.0	14	39.0	14	72.5
		15	46.0	15	45.0	15	37.0	15	67.5
		16	68.5	16	38.0	16	17.0	16	0
		17	46.0	17	40.0	17	37.0	17	84.0
		18	72.6	18	33.0	18	32.5	18	0
		19	62.4	19	16.0	19	39.0	19	33.5
		20	39.0	20	31.0	20	46.0	20	20.0
		21	54.7	21	38.0	21	20.0	21	30.0
		22	49.5	22	0	22	10.3	22	35.0
		23	29.0	23	0	23	0	23	87.0
		24	90.0	24	0	24	0	24	53.0
		Mean	**55.6**	**Mean**	**29.9**	**Mean**	**26.0**	**Mean**	**49.1**

[2/]sh = shoot height (cm)

Appendix Table 6 Shoot height of all baby corn (*Zea mays* L.) for Crop 2.

P_2O_5 (kg ha^{-1})	AMF	Rep 1 Crop no.	sh [2/] (cm)	Rep 2 Crop no.	sh (cm)	Rep 3 Crop no.	sh (cm)	Rep 4 Crop no.	sh (cm)
		1	15.0	1	27.0	1	39.0	1	24.4
		2	16.0	2	35.0	2	0	2	16.5
		3	25.0	3	62.0	3	34.5	3	22.2
		4	26.0	4	29.0	4	40.0	4	16.0
		5	13.0	5	24.0	5	20.0	5	18.0
		6	19.0	6	54.0	6	63.8	6	0
		7	41.0	7	26.0	7	30.4	7	19.0
		8	0	8	48.0	8	41.0	8	59.0
		9	0	9	0	9	28.0	9	15.0
		10	0	10	0	10	28.0	10	0
		11	0	11	0	11	12.0	11	0
		12	0	12	0	12	21.0	12	15.0
	I_1	13	58.0	13	15.0	13	51.0	13	15.0
		14	20.0	14	11.0	14	0	14	0
		15	32.0	15	56.0	15	62.0	15	0
		16	19.0	16	28.0	16	33.0	16	0
		17	17.0	17	18.0	17	45.0	17	0
		18	26.0	18	39.0	18	46.9	18	0
		19	31.0	19	49.0	19	37.0	19	67.4
		20	0	20	42.0	20	44.0	20	0
		21	0	21	0	21	0	21	0
		22	0	22	0	22	0	22	0
		23	0	23	0	23	49.0	23	0
		24	0	24	0	24	48.0	24	10.0
0		**Mean**	**14.9**	**Mean**	**23.5**	**Mean**	**32.2**	**Mean**	**12.4**
(T_1)									
		1	13.0	1	15.5	1	15.5	1	27.0
		2	43.0	2	26.0	2	13.0	2	16.0
		3	39.0	3	23.0	3	20.9	3	20.0
		4	56.0	4	24.0	4	10.9	4	12.5
		5	41.0	5	29.0	5	29.3	5	10.0
		6	18.0	6	32.0	6	34.0	6	16.0
		7	20.0	7	0	7	44.0	7	12.0
		8	78.0	8	0	8	42.0	8	0
		9	15.0	9	0	9	26.0	9	0
		10	69.0	10	0	10	48.0	10	14.0
		11	19.0	11	0	11	39.8	11	0
		12	0	12	0	12	18.0	12	0
	I_2	13	26.0	13	13.0	13	0	13	0
		14	50.0	14	29.0	14	37.8	14	0
		15	32.0	15	12.0	15	34.3	15	0
		16	76.0	16	16.0	16	33.0	16	23.7
		17	62.0	17	24.0	17	40.0	17	25.0
		18	15.0	18	0	18	58.7	18	21.7
		19	32.0	19	0	19	36.0	19	0
		20	24.0	20	0	20	40.5	20	0
		21	33.0	21	0	21	40.0	21	0
		22	23.0	22	0	22	38.0	22	0
		23	0	23	0	23	24.0	23	0
		24	0	24	0	24	23.3	24	0
		Mean	**32.7**	**Mean**	**10.1**	**Mean**	**31.1**	**Mean**	**8.2**

Appendix Table 6 (Continued)

P_2O_5 (kg ha^{-1})	AMF	Rep 1 Crop no.	sh [2/] (cm)	Rep 2 Crop no.	sh (cm)	Rep 3 Crop no.	sh (cm)	Rep 4 Crop no.	sh (cm)
		1	25.0	1	10.0	1	41.6	1	38.0
		2	58.0	2	30.0	2	18.5	2	46.0
		3	19.0	3	35.0	3	59.4	3	24.8
		4	56.0	4	20.0	4	51.0	4	28.3
		5	49.0	5	22.0	5	50.4	5	24.0
		6	73.0	6	26.0	6	74.0	6	29.7
		7	22.0	7	12.0	7	24.8	7	38.8
		8	56.0	8	16.0	8	31.0	8	28.5
		9	28.0	9	0	9	58.0	9	34.7
		10	49.0	10	0	10	51.3	10	30.0
		11	20.0	11	0	11	52.4	11	23.0
		12	0	12	0	12	72.0	12	27.0
	I_1	13	47.0	13	20.0	13	62.0	13	57.5
		14	41.0	14	12.0	14	39.8	14	14.0
		15	59.0	15	26.0	15	0	15	0
		16	52.0	16	49.0	16	58.0	16	0
		17	50.0	17	37.0	17	66.0	17	49.7
		18	89.0	18	24.0	18	56.9	18	0
		19	30.0	19	44.0	19	68.8	19	15.4
		20	69.0	20	0	20	48.0	20	30.3
		21	60.0	21	0	21	74.3	21	0
		22	29.0	22	0	22	52.4	22	12.0
		23	10.0	23	0	23	80.6	23	21.0
		24	0	24	0	24	71.0	24	49.0
60 (T_2)		**Mean**	**41.3**	**Mean**	**16.0**	**Mean**	**52.6**	**Mean**	**25.9**
		1	38.0	1	38.0	1	33.0	1	54.0
		2	46.0	2	46.0	2	46.0	2	0
		3	24.8	3	24.8	3	63.0	3	23.0
		4	28.3	4	28.3	4	41.0	4	18.0
		5	24.0	5	24.0	5	14.5	5	21.5
		6	29.7	6	29.7	6	33.2	6	0
		7	38.8	7	38.8	7	85.0	7	0
		8	28.5	8	28.5	8	33.7	8	36.2
		9	34.7	9	34.7	9	62.5	9	36.0
		10	30.0	10	30.0	10	79.3	10	13.0
		11	23.0	11	23.0	11	53.3	11	0
		12	27.0	12	27.0	12	69.4	12	15.0
	I_2	13	57.5	13	57.5	13	48.0	13	37.0
		14	14.0	14	14.0	14	71.3	14	0
		15	0	15	0	15	69.3	15	45.2
		16	0	16	0	16	58.8	16	0
		17	49.7	17	49.7	17	21.8	17	28.0
		18	0	18	0	18	34.2	18	0
		19	15.4	19	15.4	19	70.5	19	0
		20	30.3	20	30.3	20	80.3	20	36.5
		21	0	21	0	21	72.0	21	0
		22	12.0	22	12.0	22	67.4	22	0
		23	21.0	23	21.0	23	76.7	23	0
		24	49.0	24	49.0	24	0	24	46.0
		Mean	**25.9**	**Mean**	**25.9**	**Mean**	**53.5**	**Mean**	**17.1**

Appendix Table 6 (Continued)

P_2O_5 (kg ha^{-1})	AMF	Rep 1 Crop no.	sh [2/] (cm)	Rep 2 Crop no.	sh (cm)	Rep 3 Crop no.	sh (cm)	Rep 4 Crop no.	sh (cm)
		1	32.0	1	24.0	1	23.4	1	0
		2	66.0	2	27.0	2	23.7	2	23.0
		3	40.0	3	30.0	3	59.0	3	32.3
		4	25.0	4	36.0	4	49.0	4	0
		5	59.0	5	40.0	5	19.5	5	10.0
		6	24.0	6	31.0	6	31.0	6	16.7
		7	43.0	7	37.0	7	22.4	7	0
		8	77.0	8	45.0	8	23.0	8	26.4
		9	70.0	9	24.0	9	12.0	9	19.0
		10	61.0	10	30.0	10	43.0	10	0
		11	47.0	11	12.0	11	19.0	11	41.5
		12	0	12	38.0	12	26.0	12	17.9
	I_1	13	68.0	13	17.0	13	0	13	0
		14	67.0	14	57.0	14	25.5	14	15.0
		15	23.0	15	23.0	15	0	15	0
		16	33.0	16	29.0	16	59.0	16	0
		17	63.0	17	41.0	17	61.0	17	15.0
		18	16.0	18	30.0	18	50.4	18	20.0
		19	44.0	19	36.0	19	27.0	19	0
		20	50.0	20	25.0	20	67.0	20	49.0
		21	80.0	21	52.0	21	16.0	21	16.0
		22	72.0	22	18.0	22	30.0	22	0
		23	11.0	23	22.0	23	30.0	23	31.2
		24	0	24	0	24	29.0	24	0
120		**Mean**	**44.6**	**Mean**	**30.2**	**Mean**	**31.1**	**Mean**	**13.9**
(T_3)									
		1	25.5	1	9.5	1	70.0	1	14.0
		2	34.0	2	44.0	2	60.0	2	61.0
		3	72.0	3	55.0	3	13.0	3	28.0
		4	65.0	4	47.0	4	25.0	4	0
		5	69.0	5	26.0	5	25.0	5	26.0
		6	44.0	6	36.0	6	12.0	6	40.8
		7	33.0	7	33.0	7	49.0	7	38.0
		8	18.0	8	13.0	8	30.0	8	41.2
		9	74.0	9	35.0	9	25.0	9	38.2
		10	87.0	10	50.0	10	26.0	10	32.0
		11	47.0	11	38.0	11	18.0	11	47.7
		12	26.0	12	10.0	12	33.0	12	39.0
	I_2	13	46.0	13	16.0	13	52.0	13	0
		14	46.5	14	42.0	14	0	14	54.0
		15	42.0	15	63.0	15	0	15	25.4
		16	48.0	16	24.0	16	79.0	16	0
		17	71.0	17	50.0	17	0	17	82.5
		18	47.0	18	33.0	18	13.5	18	0
		19	25.0	19	36.0	19	90.0	19	0
		20	49.0	20	37.0	20	41.0	20	19.0
		21	53.0	21	20.0	21	30.0	21	29.0
		22	51.0	22	22.0	22	25.0	22	46.2
		23	71.0	23	46.0	23	15.0	23	0
		24	0	24	0	24	18.5	24	22.0
		Mean	**47.7**	**Mean**	**32.7**	**Mean**	**31.3**	**Mean**	**28.5**

Appendix Table 6 (Continued)

P_2O_5 (kg ha^{-1})	AMF	Rep 1 Crop no.	sh [2/] (cm)	Rep 2 Crop no.	sh (cm)	Rep 3 Crop no.	sh (cm)	Rep 4 Crop no.	sh (cm)
		1	19.0	1	25.0	1	46.7	1	45.2
		2	22.0	2	51.0	2	76.3	2	0
		3	24.0	3	28.0	3	58.9	3	35.1
		4	80.0	4	26.0	4	58.4	4	11.1
		5	31.0	5	45.0	5	30.0	5	41.0
		6	24.0	6	81.0	6	16.4	6	33.2
		7	90.0	7	31.0	7	61.5	7	16.0
		8	38.0	8	32.0	8	17.2	8	0
		9	15.0	9	19.0	9	32.0	9	61.5
		10	15.0	10	0	10	60.0	10	21.0
		11	0	11	0	11	63.4	11	64.0
		12	0	12	0	12	28.5	12	24.0
	I_1	13	23.0	13	51.0	13	64.3	13	0
		14	25.0	14	50.0	14	56.0	14	0
		15	27.0	15	45.0	15	68.8	15	23.2
		16	16.0	16	56.0	16	84.3	16	31.2
		17	51.0	17	26.0	17	30.4	17	53.4
		18	13.0	18	19.0	18	54.8	18	25.5
		19	56.0	19	41.0	19	76.0	19	0
		20	29.0	20	37.0	20	50.7	20	0
		21	23.0	21	0	21	48.8	21	66.0
		22	0	22	0	22	34.3	22	20.8
		23	0	23	0	23	48.0	23	44.0
		24	0	24	0	24	0	24	54.4
240		**Mean**	**25.9**	**Mean**	**27.6**	**Mean**	**48.6**	**Mean**	**27.9**
(T_4)									
		1	24.5	1	37.0	1	28.3	1	72.0
		2	33.0	2	61.0	2	30.0	2	81.0
		3	77.0	3	35.0	3	18.0	3	101.2
		4	50.0	4	28.0	4	14.0	4	45.8
		5	64.0	5	21.0	5	24.0	5	59.2
		6	58.0	6	55.0	6	20.7	6	81.3
		7	52.0	7	88.0	7	44.0	7	59.2
		8	68.0	8	40.0	8	26.8	8	97.0
		9	109.0	9	55.0	9	39.0	9	66.4
		10	0	10	86.0	10	32.3	10	96.7
		11	0	11	0	11	29.0	11	89.0
		12	0	12	0	12	14.5	12	51.5
	I_2	13	81.0	13	64.0	13	17.0	13	48.1
		14	51.0	14	71.0	14	29.5	14	30.5
		15	87.0	15	58.0	15	18.5	15	0
		16	73.0	16	87.0	16	20.2	16	66.2
		17	68.0	17	22.0	17	31.6	17	92.0
		18	20.0	18	61.0	18	29.1	18	53.2
		19	62.0	19	79.0	19	24.3	19	35.0
		20	105.0	20	19.0	20	28.0	20	85.0
		21	0	21	56.0	21	19.0	21	88.6
		22	0	22	27.0	22	27.8	22	25.0
		23	0	23	0	23	47.2	23	78.2
		24	0	24	0	24	10.0	24	30.4
		Mean	**45.1**	**Mean**	**43.8**	**Mean**	**26.0**	**Mean**	**63.9**

[2/] sh = shoot height (cm)

Appendix Table 7 Percentage of nitrogen, phosphorus and potassium concentration of shoot of baby corn (*Zea mays* L.) for Crop 1.

P_2O_5 (kg ha^{-1})	AMF	Rep	Nutrient concentration N (%)	P (%)	K (%)
0 (T_1)	I_1	1	0.919	0.074	0.656
		2	0.831	0.176	0.954
		3	1.076	0.120	0.898
		4	1.111	0.130	1.240
		Mean	**0.984**	**0.125**	**0.937**
	I_2	1	0.744	0.120	0.649
		2	0.691	0.157	0.431
		3	0.691	0.185	0.730
		4	1.496	0.130	0.962
		Mean	**0.906**	**0.148**	**0.693**
60 (T_2)	I_1	1	0.849	0.083	0.505
		2	1.024	0.176	0.870
		3	1.278	0.130	0.930
		4	0.936	0.167	0.464
		Mean	**1.022**	**0.139**	**0.692**
	I_2	1	0.271	0.111	0.484
		2	0.796	0.056	0.637
		3	0.761	0.065	0.656
		4	0.788	0.065	0.496
		Mean	**0.654**	**0.074**	**0.568**
120 (T_3)	I_1	1	0.989	0.130	0.491
		2	0.726	0.148	0.444
		3	1.269	0.139	0.595
		4	0.796	0.056	0.536
		Mean	**0.945**	**0.118**	**0.516**
	I_2	1	0.236	0.069	0.615
		2	0.866	0.139	0.841
		3	0.219	0.102	0.635
		4	0.656	0.060	0.869
		Mean	**0.494**	**0.093**	**0.740**
240 (T_4)	I_1	1	0.569	0.065	0.324
		2	0.971	0.079	0.944
		3	0.919	0.153	0.634
		4	1.059	0.194	0.700
		Mean	**0.879**	**0.123**	**0.650**
	I_2	1	0.919	0.056	0.331
		2	0.534	0.019	0.475
		3	0.814	0.157	0.983
		4	0.656	0.130	0.679
		Mean	**0.731**	**0.090**	**0.617**

Appendix Table 8 Percentage of nitrogen, phosphorus and potassium concentration of shoot of baby corn (*Zea mays* L.) for Crop 2.

P_2O_5 (kg ha^{-1})	AMF	Rep	Nutrient concentration N (%)	P (%)	K (%)
0 (T_1)	I_1	1	0.438	0.102	0.491
		2	0.268	0.069	0.721
		3	0.050	0.028	0.514
		4	0.366	0.088	0.407
		Mean	**0.280**	**0.072**	**0.533**
	I_2	1	0.195	0.056	0.502
		2	0.584	0.130	0.486
		3	0.536	0.120	0.466
		4	0.244	0.065	0.455
		Mean	**0.390**	**0.093**	**0.477**
60 (T_2)	I_1	1	0.414	0.097	0.737
		2	0.682	0.148	0.484
		3	0.390	0.093	0.482
		4	0.487	0.111	0.758
		Mean	**0.493**	**0.112**	**0.615**
	I_2	1	0.366	0.088	0.565
		2	0.487	0.111	0.382
		3	0.827	0.176	0.315
		4	0.244	0.065	0.476
		Mean	**0.481**	**0.110**	**0.434**
120 (T_3)	I_1	1	0.584	0.130	0.416
		2	0.584	0.130	0.277
		3	0.633	0.139	0.218
		4	0.584	0.130	0.505
		Mean	**0.596**	**0.132**	**0.354**
	I_2	1	0.366	0.088	0.356
		2	0.293	0.074	0.386
		3	0.584	0.130	0.266
		4	1.119	0.231	0.238
		Mean	**0.590**	**0.131**	**0.311**
240 (T_4)	I_1	1	0.293	0.074	0.334
		2	0.414	0.097	0.367
		3	1.265	0.259	0.364
		4	0.925	0.194	0.594
		Mean	**0.724**	**0.156**	**0.415**
	I_2	1	0.730	0.157	0.674
		2	1.070	0.222	0.635
		3	1.265	0.389	0.481
		4	1.119	0.231	0.475
		Mean	**1.046**	**0.250**	**0.566**

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