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Effect of arbuscular mycorrhiza and phosphorus on macronutrient contents by chilli cv. BARI morich-1

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Abstract: A pot experiment was conducted at the net house of the Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh during the period from November, 2008 to July, 2009 to evaluate the performance of different levels of phosphorus with or without mycorrhizal inoculation on macronutrient contents and their uptake by chilli cv. BARI morich-1. Nutrient contents and their uptake was significantly influenced by AM inoculation. Nutrient use efficiency in the AM inoculated plants were also significantly higher than that in uninoculated plants. The application of different levels of P lonely increased different nutrients and their uptake positively up to certain level, but at higher level influenced negatively. N, P, S, Mg contents and their uptake were the highest when P applied @ 40 Kg ha^{-1} and K and Ca in shoot and root were highest in P_{60} level. The lowest were found from 0 Kg ha^{-1}. Mycorrhizal inoculation in combination with 40 Kg ha^{-1} produced the highest N, P, K, S, Ca and Mg contents and their uptake.
Key words: Macro nutrients, arbuscular mycorrhiza, chilli.

Introduction

Mycorrhizae are integral part of most plants in nature (Pearson and Gianinazzi, 1983). Infection of the root system of the plant by these fungi creates a symbiotic (beneficial) relationship between the plant and fungus. Upon root infection and colonization, mycorrhizal fungi develop an external mycelium which is a bridge connecting the root with the surrounding soil (Toro *et al.*, 1997). One of the most dramatic effects of infection by mycorrhizal fungi on the host plant is the increase in phosphorus (P) uptake (Koide, 1991) mainly due to the capacity of the mycorrhizal fungi to absorb phosphate from soil and transfer it to the host roots (Asimi *et al*., 1980). Mycorrhizae have a worldwide recognized value for plant survival and nutrient cycling in the ecosystem. Mycorrhizal association is of great practical significance because it markedly increase the availability of several essential nutrients to plants, including P, K, Zn, Cu, Ca, Mg, Mn and Fe, especially from infertile soils. Plants are benefited by AMF in many ways. The major benefits of AMF association are: increase of mobile nutrients particularly P and micronutrients (Douds and Millner, 1999); enhancement of symbiotic N_2 fixation through increased supply (Kucey and Paul, 1982). AMF are known to improve plant phosphorus nutrition particularly in low P soils (Tinker, 1980). Chilli *(Capsicum frutescens* L.) is one of the most important spice crops of Bangladesh which belongs to the family Solanaceae and grown in the winter season. A greater portion of Bangladesh soil contains insufficient amounts of available P. Therefore, application of phosphatic fertilizer is essential for better chilli crop yield. The mycorrhizal association with plant root system has long been assumed important in the mineral nutrient of plants particularly with respect to P and other macronutrient. Hence, the prevailing situation underscores the need for a research to identify the effect of arbuscular mycorrhiza and phosphorus on macronutrient contents and their uptake by chilli cv. BARI Morich-1.

Materials and Methods

The pot experiment was conducted in the net house of the Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh during the period from November 2008 to July 2009. Soil samples were randomly collected at 0-15 cm depth and put into polyethylene bags and were taken to the laboratory. Then, it was spread on the floor and sun dried for one month. When dried, the clods were broken with hammer to make it friable. The soil was sieved to remove weeds, stubbles and hard clods. A composite soil sample was kept in a polyethylene bag for chemical analysis. The experiment consists of two factors: A. arbuscular mycorrhiza (uninoculated, and inoculated) and B. five different doses of phosphatic fertilizer (0, 20, 40, 60 and 80 kg P ha^{-1}). The crop under study was Chilli cv. BARI Morich-1. The inoculum of arbuscular mycorrhizal (AM) fungi was collected from trap crop of sorghum which was preserved in the net house, Soil Science Division of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. There were 10 treatment combinations with or without AM. The experiment was laid out in Completely Randomized Design (CRD) with four replications. To conduct the experiment, forty earthen pots were collected and each pot was poured with 10 kg finely ground mixer of soil and well decomposed cow dung with the ratio of 5:1. Nitrogen as urea, potassium as muriate of potash, sulphur as gypsum, boron as boric acid and zinc as zinc sulphate were applied according to the Fertilizer Recommendation Guide (BARC, 2005). Urea was applied in three equal splits. One third amount of urea N and full doses of other fertilizers were applied one day before seeds sowing. The rest two thirds of urea N were applied at 100 days after sowing (DAS) and 140 DAS respectively. Triple superphosphate was applied as per treatments of the experiment dividing into five doses (P_0, P_{20}, P_{40}, P_{60} and P_{80} kg ha^{-1}). Roots of sorghum with rhizosphere soil were used as AM inoculum. Fifty gram inoculum was applied per earthen pot. A layer of AM inoculum was first placed in each pot filled with sun dried soil and was covered with a thin soil layer of 2 cm in which seeds were sown. Twenty seeds of chilli treated with sodium hypochlorite for surface sterilization were sown in each pot. Pots were irrigated up to saturation to allow the soil and inoculums to settle down in the pots. The harvesting was done by uprooting the whole plants. The soil adhering to the roots could be easily thrown away by jerking and washing with water. Soil and Ca, Mg contents and their uptake by chilli plant were analyzed following the standard methods (Page *et al*., 1982). P, K and S contents and their uptake of whole plants by chilli plant were determined by the method described by Jackson (1973), Ghosh *et al*. (1983), Wolf (1982), respectively. Total nitrogen was determined

by Semi- Micro Kjeldahl method (Page *et al.*, 1982). Analysis of variance was done with the help of computer package MSTATC developed by Russel (1986) and the mean differences of the treatments were adjudged by LSD test.

Results and Discussion

Effect of AM inoculation, different levels of P and their interaction on macro nutrient contents of chilli plant

Nitrogen content in shoot and root

Inoculation of arbuscular mycorrhiza had significant effect on N content in shoot and root of chilli plant. Inoculated treatment showed the highest N content (1.14%) and the uninoculated treatment recorded the lowest N content (1.10%) (Table 1). The present findings supported the reports of Onguene and Habte (2004). Results presented in Table 2 showed that % N content in shoot and root of chilli plant varied significantly and increased progressively by P application as compared with control treatment up to a certain level. The highest N content (1.28%) was noted in P_{40} treatment. The lowest N content (0.93%) was found in P_0 level. Rashid *et al.* (2008) reported that the highest N content (0.75%) was noted in 30 kg P ha^{-1} and the lowest N content (0.64%) in brinjal seedlings was noted in 0 kg P ha^{-1}. Interaction of AM and P was significant on N content in shoot and root of chilli plant (Table 3). Application of P_{40} × I treatment showed the highest N content (1.35%) which was superior to all. The lowest N content (0.85%) was recorded in treatment P_0 × U. In all the AM and P combinations, increasing level of P had an increasing effect on N content in chilli plant but the increasing level of P after P_{40}×I treatment had a decreasing effect on N content.

Table1. Effect of arbuscular mycorrhiza (AM) on primary macro nutrient contents of shoot, root and fruit of chilli cv. BARI Morich-1

Effect of AM	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Sulphur (%)		Calcium (%)		Magnesium (%)	
	Shoot and root	Fruit	Shoot and root	Fruit	Shoot and root	Fruit	Shoot and root	Fruit	Shoot and root	Fruit	Shoot and root	Fruit
Without AM	1.10b	2.19b	1.05b	0.59b	1.32b	1.28	0.12b	0.14b	1.83	2.05	1.38	2.51
With AM	1.14a	2.24a	1.24a	0.62a	1.46a	1.30	0.13a	0.20a	1.88	2.35	1.43	2.60
SE (±)	0.013	0.012	0.025	0.015	0.010	0.013	0.0026	0.006	0.063	0.056	0.024	0.041
Level of sig.	**	**	**	**	**	NS	**	**	NS	NS	NS	NS

Table 2. Effect of different levels of phosphorus on primary macro nutrient contents of shoot, root and fruit of chilli cv. BARI Morich-1

Effect of P (kg ha^{-1})	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Sulphur (%)		Calcium (%)		Magnesium (%)	
	Shoot and root	Fruit	Shoot and root	Fruit	Shoot and root	Fruit	Shoot and root	Fruit	Shoot and root	Fruit	Shoot and root	Fruit
P_0	0.93c	1.97d	0.73c	0.44d	1.18d	1.16c	0.11cd	0.15b	1.55c	2.02b	1.23c	2.15c
P_{20}	1.12b	2.17c	1.01b	0.60c	1.29c	1.28b	0.13ab	0.16b	1.89ab	2.20ab	1.43b	2.50b
P_{40}	1.28a	2.43a	1.30a	0.74a	1.39b	1.39a	0.14a	0.20a	2.02a	2.29a	1.65a	2.98a
P_{60}	1.23a	2.37b	1.28a	0.64b	1.49a	1.36a	0.12bc	0.17ab	2.05a	2.03ab	1.49b	2.81a
P_{80}	1.06b	2.15c	1.08b	0.61c	1.23d	1.26b	0.11c	0.14b	1.75bc	1.73c	1.23c	2.34bc
SE (±)	0.021	0.019	0.039	0.024	0.016	0.021	0.0035	0.011	0.090	0.088	0.037	0.064
Level of sig.	**	**	**	**	**	**	**	**	**	**	**	**

In a column, the figure(s) having same letter are not significantly different at 5% level of probability by DMRT, NS: Not significant, P_0: 0 kg P ha^{-1}, P_{20}: 20 kg P ha^{-1}, P_{40}: 40 kg P ha^{-1}, P_{60}: 60 kg P ha^{-1}, P_{80}: 80 kg P ha^{-1}

Nitrogen content in fruit: The chilli fruit showed a marked influence of AM on N content (Table 1). The highest value of N content (2.24%) was recorded with the inoculated treatments while the non-inoculated treatment showed the lowest value (2.19%). Different level of phosphorus caused significant variation in content of AM. The highest N content was 2.43% in P_{40} treatment, which was significantly higher over other P levels and the lowest data (1.97%) was observed in P_0 level (Table 2). From the result obtained, it could be said that P level has a mutualistic relation with N content. The interaction between P and AM resulted in highly significant relation. The highest value of N content (2.50%) was reported in P_{40} × I treatment combination that was superior to all other treatment combinations. The lowest value (1.92%) was obtained in P_0 × U treatment combination (Table 3).

Phosphorus content in shoot and root: Effect of mycorrhizal inoculation on phosphorus content in shoot and root of chilli plant was significant. Data presented in Table 1 showed the highest P content (1.24%) was found in inoculated plant and the lowest P content (1.05%) was found in uninoculated plant. Jahan (2008) found that P content (1.43%) is higher in inoculated plant than uninoculated. The P content of chilli shoot and root varied significantly due to application of different P level (Table 2). Among the P level, the highest P content (1.30%) was observed at P_{40} level and the result was statistically similar with P_{60} treatment. The lowest P content (0.73%) was recorded in control treatment (P_0). Rashid *et al.* (2008) found that P fertilization increased P content of brinjal seedlings positively upto a certain level and the highest P content (0.44%) was noted in 30 kg P ha^{-1}. AM × level of P did not find significant effect on P content of chilli plant (Table 3). The highest P content (1.39%) was found in treatment P_{40} × I. In contrast, the lowest P content (0.68%) was found at treatment P_0 × U (Table 3). From this result, it was evident that both mycorrhizal inoculation and P level accelerated the accumulation of P up to a certain level and then it decreased in chilli plant. These finding also confirmed the reports of Chitdeshwan *et al.* (1998),

who studied the effect of different levels of phosphorous and VA mycorrhiza on cowpea. Soil and plant P level after harvest was increased by mycorrhizae inoculation.

Phosphorus content in fruit: Phosphorus content in fruit of chilli was significant due to the effect of mycorrhizal inoculation. The highest P content (0.62%) was found in inoculated plant and the lowest P content (0.59%) was found from uninoculated plant (Table 1). The P content in fruit varied significantly with different P levels due to application of P (Table 2). Among the P level, the highest P content (0.74%) was observed at P_{40} level. The lowest P content (0.44%) was recorded in control treatment (P_0 level). AM × level of P interaction was found highly significant on P content of chilli fruit (Table 3). The highest P content (0.78%) was found in treatment P_{40} × I which was significantly higher over all other combinations. In contrast, the lowest P content (0.42%) was found at treatment P_0 × U (Table 3).

Table 3. Interaction effect of arbuscular mycorrhiza (AM) and phosphorus on primary macro nutrient contents in shoot, root and fruit of chilli cv. BARI Morich-1

Interaction effect (AM × P)	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Sulphur (%)		Calcium (%)		Magnesium (%)	
	Shoot and root	Fruit	Shoot and root	Fruit	Shoot and root	Fruit	Shoot and root	Fruit	Shoot and root	Fruit	Shoot and root	Fruit
P_0 × U	0.85f	1.92f	0.68	0.42j	1.16g	1.14e	0.11e	0.12d	1.39	1.65c	1.19e	1.40
P_0 × I	1.01e	2.02e	0.78	0.45i	1.21f	1.18de	0.12c	0.18b	1.72	2.09ab	1.27cde	1.59
P_{20} × U	1.10de	2.12d	0.96	0.56h	1.27e	1.24cd	0.12c	0.12d	1.71	2.16ab	1.40bcd	1.87
P_{20} × I	1.15bcd	2.21c	1.06	0.65d	1.32cd	1.31bc	0.14b	0.19b	2.07	2.24a	1.47b	1.93
P_{40} × U	1.21bc	2.36b	1.20	0.70b	1.44b	1.34b	0.13bc	0.13c	1.94	2.28a	1.54b	2.02
P_{40} × I	1.35a	2.50a	1.39	0.78a	1.55a	1.45a	0.16a	0.27a	2.10	2.30a	1.76a	2.24
P_{60} × U	1.25b	2.38b	1.31	0.67c	1.44b	1.38ab	0.13bc	0.13c	2.05	2.03abc	1.42b	2.17
P_{60} × I	1.21bc	2.35b	1.25	0.61f	1.34c	1.34b	0.12cd	0.21b	2.06	2.03abc	1.56bc	2.28
P_{80}× U	1.12cd	2.16cd	1.11	0.59g	1.29de	1.30bc	0.11de	0.18b	1.90	1.81bc	1.24de	1.91
P_{80} × I	1.01e	2.15cd	1.06	0.63e	1.17g	1.23cd	0.11de	0.16bc	1.60	1.95abc	1.22e	1.96
SE (±)	0.029	0.03	0.055	0.034	0.022	0.029	0.0059	0.016	0.141	0.125	0.053	0.091
CV%	5.20	2.37	10.23	11.30	3.40	4.56	9.60	14.85	15.21	12.18	7.50	7.12
Level of sig.	**	**	NS	**	**	**	**	**	NS	*	**	NS

In a column, the figure(s) having same letter are not significantly different at 5% level of probability by DMRT, U= Non-inoculated, I= Inoculated, AM=Arbuscular Mycorrhiza, P_0: 0 kg P ha^{-1}, P_{20}: 20 kg P ha^{-1}, P_{40}: 40 kg P ha^{-1}, P_{60}: 60 kg P ha^{-1}, P_{80}: 80 kg P ha^{-1}

Potassium content in shoot and root: The application of AM significantly affected the K content in shoot and root of chilli plant. The highest K content (1.46%) was recorded when the crop was inoculated with AM. The lowest K content (1.32%) was produced by no inoculation of AM (Table 1). Jahan (2008) noted that AM inoculation gave higher K content (1.33%) than uninoculated plant. Potassium content in chilli shoot and root differed significantly due to different levels of P application. The highest K content (1.49%) was obtained when the crop was fertilized with 60 kg P ha^{-1} that was superior to all P levels and the lowest K content (1.18%) was found from control (Table 2). From the above findings, it showed that K content was greatly affected by P application. Jahan (2008) carried out an experiment for raising chilli seedlings using 5 levels of P (0, 20, 40, 60 and 80 kg P ha^{-1}) and reported that P fertilization increased K content positively up to a certain level and the highest K content (1.45%) was noted in 30 kg P ha^{-1}. The interaction effect of phosphorus and AM on K content of chilli shoot and root was significant (Table 3). The highest K content (1.55%) was recorded when mycorrhizal inoculant was applied with P_{40} level, which was statistically the best of all. The control treatment P_0 × U showed the lowest K content (1.16%).

Potassium content in fruit: Potassium content in fruit of chilli was non-significant due to the effect of mycorrhizal inoculation. The highest K content (1.30%) was found in inoculated plant and the lowest K content (1.28%) was found from uninoculated plant (Table 1). The K content in chilli fruit varied significantly with different P levels (Table 2). Among the P levels, the highest K content (1.39%) was observed at P_{40} treatment which was superior to all and the lowest K content (1.16%) was recorded in control treatment. AM × level of P was found highly significant effect on K content of chilli fruit (Table 3). The highest K content (1.45%) was found in treatment P_{40} × I which was identical to P_{60} × U. In contrast, the lowest K content (1.14%) was found at P_0 × U.

Sulphur content in shoot and root: The content of S in shoot and root of chilli plant was significant due to AM inoculation (Table 1). The highest S content (0.13%) was recorded with AM inoculation and the lowest S content (0.11%) was recorded without AM inoculation. Different P levels significantly influenced the S content in shoot and root of chilli plant (Table 2). Application of sulphur @ 40 kg ha^{-1} gave the highest S content (0.14%) which was identical with P_{20} level. The lowest S content was recorded in P_{80} and P_0 treatment which was 0.11%. Rashid *et al.* (2008) noted that the highest S content in brinjal seedlings was found when 15 kg P ha^{-1} was applied.

Significant variation of S content due to interaction effect of AM and level of P was noted in chilli. The highest S content (0.16%) was recorded in P_{40} × I treatment, which was superior among all other combinations and the lowest S content (0.10%) was found from P_0 × U treatment combination (Table 3).

Sulphur content in fruit: Sulphur content in fruit of chilli was significant due to the effect of mycorrhizal inoculation. The highest S content (0.20%) was found in inoculated plant and the lowest S content (0.14%) was found from uninoculated plant (Table 1). The S content varied significantly with different P levels (Table 2). Among the treatments, the highest S content (0.20%) was observed at P_{40} level that was identical to P_{60} level. The lowest S content (0.14%) was recorded in P_{80} treatment.

Interaction effect of AM and level of P was found highly significant on S content. The highest S content (0.27%) was found in treatment P_{40} × I which was superior to all. In contrast, the lowest S content (0.12%) was found in P_0 × U (Table 3).

Calcium content in shoot and root: Arbuscular mycorrhiza inoculation significantly enhanced the Ca content in shoot and root of chilli plant. The highest Ca content (1.88%) was found when the crop was inoculated with arbuscular mycorrhiza, while the uninoculated plants showed lowest Ca content (1.55%) (Table 1). The results showed significant variation in Ca content in shoot and root of chilli plant due to the effect of different levels of P (Table 2). The treatment P_{60} accumulated maximum shoot Ca content (2.05%). The treatments P_0 accumulates minimum Ca content (1.55%) whereas P_{20}, P_{40} and P_{60} treatments produced statistically similar result. Rashid *et al.* (2008) noted that P fertilization increased Ca content in brinjal seedlings positively upto a certain level and the highest Ca content (0.76%) was noted in 30 kg P ha^{-1} and the lowest Ca content (0.65%) was noted in 0 kg P ha^{-1}. Combination of AM and levels of P did not vary in Ca content in chilli plant (Table 3). Though the highest Ca content (2.10%) was achieved from P_{40} × I treatment which was higher than all other treatments. The lowest Ca content (1.39%) was found from P_0 × U treatment combination.

Calcium content in fruit: Arbuscular mycorrhiza inoculation had significant effect on the Ca content in chilli fruit (Table 1). The highest Ca content (2.35%) was found when the crop was inoculated with arbuscular mycorrhiza. While the uninoculated plants showed the lowest Ca content (2.05%). Influence of three arbuscular mycorrhizal fungi and phosphorus on growth and nutrient status of taro was observed by Li *et al*. (2005). They opined that inoculation with AM fungi significantly increased the contents of calcium (Ca). Significant variation in Ca content in fruits of chilli due to the effect of different levels of P was observed (Table 2). The treatment P_{40} accumulated maximum Ca content (2.29%) in fruit, which was statistically superior to other treatments except P_{20} and P_{60} level. The treatments P_{80} accumulated minimum Ca content (1.73%). Whereas P_{20}, P_{40}, P_{60} levels produced statistically similar result but superior to control. Interaction effect of AM and levels of P significantly increased Ca content in chilli fruits (Table 3). The highest Ca content (2.30%) was achieved P_{40} × I treatment which was superior to P_0 × U and P_{80} × U treatments only. The lowest Ca content (1.65%) was found from P_0 × U treatment combination.

Magnesium content in shoot and root: Magnesium content did not show significant effect by inoculation with AM (Table 1). Though higher Mg content (1.43%) was produced when the crop was inoculated with mycorrhiza and the lower Mg content (1.38%) was obtained from uninoculated treatment. Magnesium content differed significantly due to different levels of P application (Table 2). The highest Mg content (1.65%) was observed when the crop was fertilized with 40 kg P ha^{-1} which was superior to all P levels. The lowest in Mg content (1.23 %) was obtained from P_0 and P_{80}, respectively. It could be concluded that increase in P levels caused considerable increase in Mg content but after a certain level it decreased. Rashid *et al.* (2008) concluded that P fertilization increased Mg content in brinjal seedlings positively upto a certain level and the highest Mg content (0.76%) was noted in 30 kg P ha^{-1}. The results on the interaction effect of inoculation of arbuscular mycorrhiza and different levels of P showed significant variation in Mg content (Table 3). The highest Mg content (1.76%) was produced by 40 kg P ha^{-1} × AM inoculant which differed from all other treatment combinations. Control treatment combination (P_0 × U) produced the lowest Mg content (1.19%).

Magnesium content in fruit: Magnesium content did not show any significant effect by inoculation with AM in chilli fruit (Table 1). Though higher Mg content (2.60%) was produced when the crop was inoculated with mycorrhiza and lower Mg content (2.51%) was obtained from uninoculated treatment. Phosphorus had significant effect on Mg content in chilli fruit (Table 2). The highest Mg content (2.98%) was observed when the crop was fertilized with 40 kg P ha^{-1} which was identical to P_{60} level only. The lowest Mg content (1.25%) was obtained from P_0 treatment. Interaction effect of inoculation of arbuscular mycorrhiza and different levels of P showed significant variation in Mg content (Table 3). The highest Mg content (2.28%) was produced by 60 kg P ha^{-1} × AM inoculant. Control treatment combination P_0 × U produced the lowest Mg content (1.40%).

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