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EFFECT OF ROCK PHOSPHATE AND FARMYARD MANURE APPLIED WITH EFFECTIVE MICROORGANISMS ON THE YIELD AND NUTRIENT UPTAKE OF WHEAT AND SUNFLOWER CROPS

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Abstract

Field experiments were conducted to investigate the effects of rock phosphate (RP) and farmyard manure (FYM) applied with and without effective microorganisms (EM) on the yields and plant P uptake of wheat and their residual effect on subsequent sunflower crop during Rabi 2008-09 and Kharif season 2009. The experiments were laid out according to the Split-Plot Randomized Complete Block Design with three replications with a plot size of 5m x 11m. Statistical analysis of the data revealed that the effect of EM in main-plot was significant ($p\leq0.05$) on 1000-grain weight, grain yield and total dry matter yield of wheat. The sub-plot, where various combinations of RP and FYM were applied also indicated significant ($p\leq0.05$) effects on these parameters. Significant ($p\leq0.05$) interaction between EM applied with RP and FYM was recorded for plant height, 1000-grain weight and grain yield, while non-significant for total dry matter yield of wheat. Plants N and P uptakes and post harvest soil extractable P content improved significantly ($p\leq0.05$) by EM inoculation with RP and FYM and their interactions. The residual effect of EM application was non-significant on plant height, head diameter, grain yield and total dry matter yield of sunflowers, while significant ($p\leq0.05$) for sub plot treatments regarding these parameters. The interaction between EM and RP applied with FYM was significant ($p\leq0.05$) for head diameter, grain yield, while non significant for plant height and total dry matter yield of sunflower. The residual effect of EM was significant ($p\leq0.05$) for N and P uptake by sunflower plants. These results suggest that solubility of P may be enhanced from RP through application with FYM and EM, which has the potential to improve plants N and P uptake and crops yields on sustainable basis.

Key words: Rock phosphate, Farmyard manures, Effective microorganisms, Yields, Wheat, Sunflower

Introduction

Phosphorus is the second essential macronutrient for plant growth, which plays a vital role in transfer of energy within the various parts of plant and root development for higher water and nutrient use efficiency (Singh *et al*., 1998; Sharma, 2005; Shafiq, 2007). Phosphorus deficiency is common in Pakistani soils (Rashid, 2005). To combat this deficiency, 566,000 nutrient tons of P against its requirement of 760,000 nutrient tons is imported (Anon., 2010).

Pakistan has Rock phosphate (RP) deposits in Hazara area of Khyber Pakhtunkhwa Province. Due to the huge amount of exchange incurred on imports, its high prices within the country and the shortage during the peak season, it becomes necessary to explore new ways and means to utilize indigenous resources of RP as phosphate fertilizers, for better crop production. The insoluble P content of RP may be converted to the soluble form by chemical acidulation and biological means. The biological solubilization of RP is e environment-friendly option. The major microbial means by which insoluble P compounds are mobilized is by the production of organic acids. The organic acids thereby produced convert tri-calcium phosphate (RP) to di and mono-basic phosphates with the net result of an enhanced availability of the element to the plant. The type of organic acids produced and their amount affect the amount of P solubilized from RP.

The importance of application of FYM with chemical fertilizers and composted with RP to improve crops yield is very well established (Shafi *et al*., 2012 and Ibrahim *et al*., 2008). However, the lesser amounts of plant essential nutrients in these manures and the lengthy process of decomposition discourage farmers from using it. Addition of acid creating microbes enhances the process of P availability, hence EM having pH 3.5 may further increase the process of P availability. The EM contains selected species of microorganisms including lactic acid bacteria, yeasts, smaller numbers of photosynthetic bacteria, actinomycetes, fermentative fungi and other types of organisms. All of these are mutually compatible with one another and can coexist in liquid culture. The lactic acid is a strong sterilizing compound enhances decomposition of organic matter. The lactic acid producing bacteria promote the decomposition process and remove undesirable effects of un-decomposed organic material. It improves the physical, chemical and biological environment of the soil (Higa & Parr, 1994). Many researchers have reported that application of EM may enhanced the crops yields, increase the bio availability of nutrients. Hussain *et al*., (2000) reported the agronomic merits of EM in a rice-wheat cropping system. In all cases, the grain and straw yields from EM alone were higher than the controls. The EM applied in combination with FYM caused a significant increase in nutrient uptake by the grain and straw of each crop. The uptake of NPK by both crops was higher for EM alone than for the control. Similar supportive conclusions have been reported by Kishore (2000), Xu *et al*., (2000) and Yamada & Xu (2001). The combined application of RP with FYM and EM help to improve P solubility from RP and decrease the time span of their decomposition (Sharif *et al*., 2014 and Ahmad *et al*.,).

Wheat is the major staple food of Pakistan and is grown in almost all cropping patterns of the country. Wheat was cultivated on an area of 9042 thousand hectares with 25 million tons of production. The average yield of the country is 2765 kg ha^{-1} which is far below the average yield of many countries. Sunflower (*Helianthus annuus* L.*)* is grown for edible oil extraction and it ranks fourth as the most important edible oil crop worldwide. In Pakistan sunflower crop was grown on an area of 319747 ha with a production of 420487 tons. The average yield of the crop in Pakistan is 1315 kg ha^{-1}. (Anon., 2010). Keeping in view the importance of P in crop production and its solubility enhancement through biological means, studies were conducted to determine the effects of RP and FYM applied with and without EM on yields and plant P uptake of wheat and their residual effect on subsequent sunflower crop.

Materials and Methods

Field experiments were conducted to investigate the effects of RP and FYM applied with and without EM on the yields and plant P uptake of wheat and their residual effect on subsequent sunflower crop in same layout without application of any P fertilizer during Rabi 2008-09 and Kharif season 2009.

Wheat variety GA-2000 was sown under rain-fed conditions maintaining a seed rate of 120 kg ha^{-1}. The soil moisture content, calculated at the time of sowing by the Gravimetric method (Gardner, 1986) was 12.3%. The experiment was laid out according to the Split-Plot Randomized Complete Block Design with three replications, with a plot size of 5m x 11m. The treatments of EM, i.e. with EM (+)' and without EM (-)' were kept in the main plot, while the sub-plot contained the treatment contain different combinations of FYM and RP. The soil under investigations was silt loam, alkaline calcareous in nature, pH 7.76, low in organic matter, N and P contents with 10 to 93 mm rainfall and average day temperature of 10 to 30°C during plant growth period.

Rock phosphate was properly mixed with FYM and EM and applied to the soil in their respective treatments. The EM solution was prepared with 1:1:100 (EM: molasses: water) and kept for three days to activate the microbes and applied to the soil prior to sowing, with a hand-pump spray at the rate of 200 L ha^{-1}. Also, one foliar spray of EM (1:1:500) was applied to the respective treatments of M (+), while the same amount of water was sprayed on the remaining treatments M (-) at plants tillering stage to minimize any experimental error.

Nitrogen dose of 100 kg ha^{-1} was uniformly applied to all treatments, either from urea or urea and FYM. No P was applied to the crop from chemical fertilizer. At crop maturity, data on plants height, total dry matter and grain yield of wheat were recorded.

Residual effect of RP and FYM applied with EM was determined on the yield and P uptake of Sunflower in same layout of wheat crop during 2009 following the same experimental design and treatments combinations: No pre sowing irrigation was applied to the field for maintaining the soil optimum moisture level because the soil already had a moisture level of 19%. Each treatment was separately ploughed and planked to avoid treatments mixing and disturbing embankments around the plots. The land preparation was done with the help of a small tractor. Minimum of 14.93 mm and maximum of 153.99 mm with total of 329 mm rainfall and 27 to 30°C average temperature were recorded during plant growth period.

Sunflower crop was sown with the help of a cultivator, maintaining a row-to-row distance of 65 cm. Manual thinning was done to maintain a plant to plant spacing of 15 cm in all of the treatments. No irrigation or other inputs were applied to the crop. Manual weeding was done twice with an interval of one month. Ten randomly selected plants from each experimental unit were measured to record the head diameter reading. Plants height was recorded by randomly selecting ten plants from each treatment. The central three rows of each experimental unit were harvested, total dry matter yield was noted and threshed manually to record the grain yield. The Post harvest soil samples were taken from every treatment for determining the soil physico chemical properties. Plants N concentrations of wheat and sunflower were determined by Total N by Kjeldhal method of Bremner (1996). Available P_2O_5 in FYM was analyzed through Mehlic-3 protocol (Mehlic, 1984). Total P concentration in RP and FYM was determined by the procedure of Olsen & Sommers (1982). Soil pH was determined by McClean, (1982) Procedure. Soil texture was determined by the method of Koehler (1984). For the determination of soil NO_3-N, extractable P and K, a multi element determination extractant Ammonium Bicarbonate –Diethylene Triamine Penta Acetic Acid (AB-DTPA) was used by the method as described by Soltanpour & Schwab (1977). Organic matter content in soil was determined by the Titration Method (Nelson & Sommers, 1982).

The data recorded regarding different parameters of these experiments were compiled and analyzed for Analysis of Variance and Least Significant Difference (LSD) through the computer software Statistix-8.1, as prescribed by Steel & Torrie (1980).

Results and Discussion

Analysis of FYM and RP used in the experiments are given in Table 1, while F values for different parameters recorded are presented in Table 2. The analysis indicated that the effect of EM was significant ($p\leq0.05$) on grain yield, total dry matter yield, plant height and thousand grains weight. The subplot of various combinations of RP and two types of FYM including commercial manure of poultry litter (FYM-1) and self prepared farmyard manure from cow dung (FYM-2) applied also showed a significant ($p\leq0.01$) effect on all studied parameters. The interaction between EM and RP applied with FYM was significant ($p\leq0.05$) for plant height, thousand grains weight and grain yield, while non-significant for the total dry-matter yield of wheat.

Table 1. Analysis of FYM and RP used in the experiments on the effects of RP and FYM applied with and without EM.

Inputs	Total N	P_2O_5		K	TOC	pH
		Total	Extractable (%)			
RP	-	22.00	0.001	-	-	7.92
FYM-1	1.62	2.42	0.36	2.32	32.11	7.14
FYM-II	1.42	2.32	0.31	2.23	34.21	7.54

TOC = Total Organic Carbon, FYM-1 = Commercial Manure, FYM-2 = Self prepared Manure

Table 2. F Values of ANOVA for effect of RP & FYM applied with and without EM on yield and yield components of wheat.

SOV	DF	Plant height (cm)	1000 grains weight (g)	Grains yield (kg ha^{-1})	TDM
EM	1	75.13*	637.00**	29.63*	67.36*
RP+ FYM	5	148.37**	195.94**	399.91**	144.92**
RP+FYM x EM	5	0.58 NS	4.07*	3.32*	3.43*

* = significant at $p\leq 0.05$, ** = significant at $p\leq 0.01$, NS= non-significant.

Plant height: Plants height averaged across the treatments of RP and FYM (sub-plot) for the EM effect in the main plot showed significant ($p\leq0.05$) variation (Table 3). The treatment that received EM gave higher values of plant height than the plot without EM. The treatments included in the sub-plot (combinations of RP and FYM) averaged across the EM levels of the main plot revealed a significant ($p\leq0.01$) effect on plants height. The maximum plant height of 104 cm among the sub plot treatments was recorded in the plots where RP was applied along with FYM-1, followed by 100 cm produced by the treatment of RP and FYM-2. Interaction effect between the main plot and the sub plot (EM x RP and FYM) was non-significant on plant height. However, the maximum plant height of 106 cm was recorded in the treatment where EM (+) interacted with FYM-1. Data revealed that the effect of RP and FYM was more pronounced when applied along with EM. Awaad *et al*., (2008) reported similar effect of P sources applied along with manure and phosphate solubilizing microbes on the plant height of canola. The findings of Moore & Miller (1994) are also in accordance with these results who concluded that effectiveness of RP enhanced when applied along with composts.

Thousand grains weight: The statistical analysis of the main plot of EM levels for 1000 grains weight showed significant ($p\leq0.01$) variations. The data that was averaged across the sub plots for EM effect indicated that the treatment of EM(+) superseded the EM(-) by producing a 4.5% higher 1000 grains weight (Table 3). Similarly, the sub-plot of various combinations of RP and FYM averaged across the EM levels showed significant ($p\leq0.01$) effects on 1000 grains weight (Table 3). The highest 1000 grains weight value of 379 g was recorded in the plot where RP and FYM-1 were applied. The treatment RP and FYM-1 superseded all of the sub plot treatments and produced 19.6% and 17% increased 1000 grains weight over control and RP alone, respectively. The interaction effect of sub plot x main plot (EM x RP and FYM) was significant at $p\leq0.05$ (Table 3). The trend of increase was same as that of the main plot and the sub plot. The highest 1000 grains weight of 388 g was recorded with the treatment RP and FYM-1 x EM (+). The findings of Awaad *et al*., (2008) and Moore and Miller (1994) support these results.

Wheat grains yield: Data on grain yield revealed that significantly ($p\leq0.05$) higher yield of 2967 kg ha^{-1} was obtained from EM (+) showing a 7.8% yield advantage over EM (-). The data averaged across the EM levels (main plot) for comparison of sub plot effects showed that the significantly ($p\leq0.01$) highest grain yield of 3510 kg ha^{-1} was produced in the treatment of RP and FYM-1, followed by RP and FYM-2 with no statistical difference (Table 3). The interaction of EM x RP and FYM for grain yield was significant at $p\geq0.05$. The highest grain yield of 3634 kg ha^{-1} was found with EM (+) x RP and FYM-1. Similar conclusions have been reported by Akande *et al*., (2005), with applied poultry manure along with RP on the yield of maize followed by cowpea. Findings of Awaad *et al*., (2008), Sharif *et al*., 2013 and 14 and Moore & Miller (1994) supported these results.

Total dry matter yield: The main plot (EM levels) analyzed data averaged across the sub plots showed significant ($p\leq0.05$) variations between EM (+) and EM (-). Yield increase of 8% was recorded with the application of EM over treatment of without EM. The sub plot data of RP and FYM combinations averaged across main plot showed significant ($p\leq0.05$) effect of treatments on total dry matter yield (Table 3). The highest total dry matter yield of 13090 kg ha^{-1} was noted in the treatment RP and FYM-1, which was statistically at par with yield of 13040 kg ha^{-1} produced by treatment RP and FYM-2 when arranged across the main plots (Table 3). These results are in accordance with findings of Amanullah *et al*., (2010), Akande *et al*., (2005), Awaad *et al*., (2008) and Moore & Miller (1994).

Table 3. Effects of RP and FYM applied with and without EM on yield and yield components of wheat.

EM	Control	RP	FYM-1	FYM-2	FYM-1+RP	FYM-2+RP	Mean
Plant height (cm)							
EM(+)	85.1 G*	86.0 G*	96.3 CD*	92.7EF*	106.4 A*	101.6 B*	94.69 a*
EM(-)	83.4 G	84.3 G	93.9 DE	90.4 F	102.0 B	98.5 C	92.04 b
Mean	84.2 e	85.2e	95.1 c	91.6 d	104.2 a	100.10 b	-
1,000 grains weight (g)							
EM (+)	319 G*	328 F*	356 D*	355 D*	388 A*	3369 B*	354 a*
EM(-)	315 G	319 G	336 E	334 EF	370 C	360 D	339 b
Mean	317 e	324 d	346 c	345 c	379 a	370 b	-
Grain yield (kg ha^{-1})							
EM(+)	2128 F	2280 E	3115 B	3030 C	3634 A	3355 B	2967 a
EM(-)	2092 *F	2097 *F	2903 *C	2815 D*	3387 B*	3050 C*	2747b*
Mean	2110 c	2188 c	3009 b	2923 b	3510 a	3202 ab	-
Total dry matter yield (kg ha^{-1})							
EM(+)	9340 DE*	9890 D*	12610 B*	12240 B*	13550 A*	13670 A*	11880 a*
EM(-)	9070 E	9590 DE	11250 C	10880 C	12530 B	12510 B	10970 b
Mean	9210 d	9740 c	11930 b	11590 b	13040 a	13090 a	-

Means followed by different letters are statically different from each other at $p \leq 0.05$

FYM-1= commercial manure, FYM-2= self-prepared manure, EM(+)=With EM, EM(-)= Without EM

Postharvest soil NO_3-N and extractable P contents: The data presented in Table 4 revealed that the effect of EM levels was significant ($p \leq 0.05$) on post-harvest soil NO_3-N. The treatment inoculated with EM gave higher NO_3-N content than the treatment without EM in main-plot. The effect of combinations of RP and FYM in sub plot was also significant on soil post-harvest NO_3-N content on the treatment receiving FYM with RP. However, post-harvest soil NO_3-N content of FYM-2 alone was significantly ($p \leq 0.05$) lower than the rest of the FYM treatments. The interaction effect of EM x RP+FYM was significant ($p \leq 0.01$) on post-harvest soil NO_3-N.content. The highest value of 1.59 ±0.9 mg kg^{-1} was recorded in the treatment receiving FYM along with EM followed by treatment FYM-1 and RP with 1.54 mg kg^{-1}.

Post-harvest soil extractable P content: The extractable P content recorded after the harvest of crop showed significant ($p \leq 0.01$) variations among the EM levels, various combinations of FYM and RP and interaction between EM and RP and FYM combination (Table 4). The results of EM levels in main plot showed that plots with EM (+) showed comparatively higher extractable soil P content than EM (-). The data averaged across the EM levels for RP and FYM combinations effect showed that the higher extractable P of 4.76 mg kg^{-1} was recorded in the treatment receiving FYM-1 and RP, followed by FYM-2 and RP with 4.55 mg kg^{-1}. The trend of interactions was similar to that of EM levels and combinations of RP and FYM. The results showed that the treatment of FYM and RP gave highest extractable soil P content when applied with EM.

Plants N and P Uptake: It is evident from the data averaged across the EM levels for RP and FYM combination effect on plant N uptake showed significant ($p \leq 0.01$) variations among the treatments (Table 5). The highest N uptake of 223.35 kg ha^{-1} was observed in treatments where RP and FYM-2 were applied with significant interactions between main and subplots. Comparatively higher N uptake by wheat plants was noted by the treatments receiving RP and FYM with EM. Data regarding Plants P uptake by wheat plants revealed significant ($p \leq 0.05$) increases by the application of RP and FYM with EM irrespective of the type of FYM (Table 5). The highest plants P uptake of 25.3 and 24.4 kg ha^{-1} by wheat were recorded in the treatments receiving RP and FYM with EM, irrespective of the types of FYM. The interaction of EM levels (main-plot) and RP and FYM combinations (sub plot) also showed significant ($p \leq 0.05$) effect on plant P uptake of wheat. Hussain *et al*., (2000) and Alkande *et al*., (2005) are in agreement with our results who reported comparatively higher plant N and P uptakes with the application of EM.

Residual effect of RP and FYM applied with EM: Experiment on the residual effect of RP and FYM applied with and without EM on yield and plant P uptake of sunflower was conducted in Kharif 2009 soon after the harvest of wheat crop. The split plot analysis of variance where EM was in main-plot and RP and FYM in sub plots showed that residual effect of EM levels was non-significant on plant height, head diameter, grain yield and total dry matter yield of sun flower, while significant ($p \leq 0.01$) on sub plot treatments regarding these parameters. The interaction between EM and RP and FYM was significant ($p \leq 0.05$) for head diameter and grain yield, while non-significant for plant height and total dry matter yield of sunflower (Table 6).

Table 4. Effects of RP and FYM applied with and without EM on post harvest soil NO_3-N and P contents.

EM	Control	RP	FYM-1	FYM-2	FYM-1+RP	FYM-2+RP	Mean
Post harvest soil NO_3-N content (mg kg $^{-1}$)							
EM+	11.03 E*	11.13 E*	15.83 A*	15.20BC*	15.8 A*	15.97 A*	14.178 a*
EM-	10.73 E	11.10 E	14.80 C	13.93 D	15.4 AB	14.43 CD	13.40 b
Mean	10.88 c	11.11 c	15.32 a	14.57 b	15.65a	15.20 a	-
Post harvest soil extractable P content (mg kg $^{-1}$)							
EM+	1.91 F	1.97 F	2.87 D	3.00 D	4.94 A	5.09 A	3.29 a
EM-	1.84 F	1.91 F	2.48 E	2.56 E	4.15 C	4.42 B	2.89 b
Mean	1.88 d	1.94d	2.67c	2.78 c	4.55 b	4.76 a	-

Means followed by different letters are statically different from each other at p≤ 0.05

FYM-1= Commercial manure, FYM-2= Self-prepared manure, EM(+)=With EM, EM(-)= Without EM

Table 5. Plants N and P uptake as influenced by RP and FYM applied with and without EM.

EM	Control	RP	FYM-1	FYM-2	FYM-1+RP	FYM-2+RP	Mean
Plant N Uptake (kg ha^{-1})							
EM+	85.32 F*	94.71 E*	165.43D*	187.13C*	217.66 AB*	223.35AB*	162.36^{NS}
EM-	83.31 EF	88.43 EF	163.25 D	182.38 C	211.45 A	219.3 B	158.02^{NS}
Mean	84.32 f	91,57 e	164.34 d	184.76 c	214.56 a	221.33 c	-
Plant P Uptake (kg ha^{-1})							
EM+	12.4 E*	12.8 E*	19.1 C*	19.5 0C*	24.4 A*	25.3 A*	18.92A*
EM-	11.3 E	11.9 E	17.3 D	17.4 D	22.2 B	22.9 B	17.17 B
Mean	11.85 c	12.35 c	18.2 b	18.45 b	23.3 a	24.1 a	-

* Means followed by different letters are statically different from each other at p≤ 0.05

FYM-1= commercial manure, FYM-2= self-prepared manure, EM(+)=With EM, EM(-)= Without EM

Table 6. F Values of ANOVA for plant height, head diameter and grain yields of sunflower as affected by the residual effect of RP and FYM applied with and without EM.

SOV	DF	Plant height (cm)	Head Diameter(cm)	Grain yield (kg ha^{-1})	TDM yield
EM	1	0.31 ^{NS}	11.90 ^{NS}	6.09 ^{NS}	0.9 ^{NS}
RP+ FYM	5	28.20**	24.06**	1122.09**	3271.1**
RP+FYM x EM	5	1.52 ^{NS}	3.45*	30.6*	4.3 ^{NS}

* = significant at p≤ 0.05, ** = significant at p≤ 0.01, NS= non significant

Plant height: Data presented in Fig. 1 revealed that the main plot where EM was applied to the previous crop of wheat showed non-significant effect on plant height. The data averaged across the main plot (EM levels) for sub plot (RP and FYM) effect showed significant (p≤0.01) variation in plant height. The significantly highest values of plant height of 158 cm and 157 cm were recorded in the treatments of RP and FYM-2 and RP and FYM-1 with non-significant difference. The residual effect of both types of FYM was statistically at par with each other. The comparison of averaged data of all the three statistical groups of subplot showed that RP and FYM (group A) produced 3% and 5.8% increased plant height over statistical group B and C respectively, showing effectiveness of RP when applied along with FYM. The interaction effect of EM and RP and FYM was non-significant

Head diameter: Head diameter attributes to grain yield by influencing the number of seed per head. The data revealed that EM effect was non-significant on head diameter however, it generally increased the head diameter by 16.7% (Fig. 2). The treatments effect of various combinations of RP and FYM applied to the previous crop of wheat was significant (p≤0.01). Maximum head diameter of 19.01 cm was recorded in the treatment where RP and FYM-2 were applied. The interaction between EM and various combinations of RP and FYM remained non significant on head diameter of sunflower.

Grain yield of sunflower: The data averaged across the various combinations of RP and FYM (subplot) for main-plot showed non-significant residual effect on grain yield of sunflower. However, the effect of various combinations of RP and FYM applied to previous crop showed significant (p≤0.05) residual effect on grain yield of sunflower (Fig. 3)). The grain yield ranged from 1882 to 2545 kg ha^{-1} with application of various treatments. The highest grain yield was recorded in treatment where RP was applied along with FYM-2 to the previous crop of wheat. The comparison of averaged data of FYM alone treatments with RP and FYM showed effectiveness of RP applied to the previous crop. The interaction between EM levels and various combination of RP was also significant (p≤0.05). The highest grain yield of 3634 Kg ha^{-1} was obtained from EM(+)x RP and FYM-1. Selvi *et al*., (1997) recorded similar residual effects of RP when applied with organic manure and bio-fertilizers on grain yield of black gram crop. Akande *et al*., (1998) reported that the agronomic efficiency of RP was more pronounced on second year crop of maize as compared with first year's crop. The findings of Kishore (2000) also support these results regarding effectiveness of EM application in crop production.

Total dry matter yield: The data averaged across the subplot for mainplot effect of EM levels showed that application of EM(+) showed non-significant difference from EM(-). However, the data averaged across the main plot to concluded the effect of various combinations of RP and FYM in sub plot showed significant ($p \leq 0.01$) effect (Fig. 4). The treatment receiving RP and FYM-2 to the previous crop gave significantly ($p \leq 0.01$) higher dry matter yield of 9582 kg ha^{-1}, followed by RP+FYM-1 with 9404 kg ha^{-1}. The comparison of averaged data of FYM alone treatments with RP and FYM treatment showed that RP and FYM gave increased dry matter yield of 9.7% over FYM alone revealing effectiveness of RP towards the dry matter yield of sunflower. The interaction of EM and various combinations of RP and FYM showed significant ($p \leq 0.05$) effect on dry matter yield of sunflower. The highest dry matter yield was obtained from the treatments receiving RP and FYM, irrespective of the EM levels and types of FYM. The findings of Akande *et al*., (1998) and Kishore (2000) support our results as they stated that effectiveness of RP was more pronounced on the succeeding crops and EM application may increase crop yields.

Plants N and P uptake: The data analyzed according to the split plot design showed that EM levels exerted non significant effect on plant N uptake However, the data averaged across the EM levels for RP and FYM combination effect on plant N uptake showed significant ($p \leq 0.01$) variations among the treatments (Fig. 5). The highest N uptake of 221 kg ha^{-1} was recorded in the treatments where RP and FYM-2 were applied to the previous crop. The interaction of main plot and sub plot treatments showed significant effect on plant N uptake. The highest uptake of N by sunflower was recorded in those treatment receiving RP and FYM along with EM, irrespective of FYM types in wheat.

The data presented in Fig. 6 showed that main plot effect was significant ($p \leq 0.05$) on plant P uptake of sunflower. The treatment receiving EM showed 7.18% increased P uptake over treatment without EM. The sub plot effect where various RP and FYM combinations were applied to the previous crop showed also significant ($p \leq 0.01$) effect on P uptake. The highest plants P uptake was recorded in the treatments receiving RP along with FYM, irrespective of the kind of FYM and EM levels.

The average of treatments receiving RP and FYM, irrespective of their kind (group A) gave 35.5% and 118% increased P uptake values over FYM only (group B) and nil FYM (group C), respectively. These results confirm the effectiveness of RP when applied with FYM. The interaction of EM levels (main plot) and RP and FYM combinations (sub plot) also showed significant ($p \leq 0.05$) effect on plant P uptake of sunflower. The highest value of 23.797± 0.137 kg ha^{-1} was recorded in the treatments receiving RP and FYM along with EM(+), irrespective of the kind of FYM. These results are supported by the findings of Kucy (1987), who reported higher P uptake in succeeding crop of bean when RP was applied with *Micorrhizal* fungi. Hussain *et al*., (2000) also reported comparatively higher plant nutrients uptake with the application of EM. Our results are also in accordance with the findings of Akande *et al*., (2005).

Rock phosphate is a complex tri-calcium phosphate and is insoluble in water (Brady, 1990; Das, 2005). Total reserves of RP in this region are about 35.7 million tons have potential to sustain annual production for 30 years, more than country requirements (Anon., 2006). The main factor reported for P solublization is the action of various acid creating microbes in soil (Rashid *et al*., 2005). Significantly increased yields and plants nutrients uptake were recorded by RP addition with different organic materials (Sharif *et al*., 2011; Matiullah, 2012: Ali *et al*., 2014). Awaad *et al*., (2009) evaluated the effectiveness of phosphate ores as source of P to the canola crop when applied with farm yard manure and phosphate solublizing bacteria. The plant height, number of pods $plant^{-1}$, pods weight, grain yield and biomass yield increased significantly with the application of super phosphate or phosphate ores alone and combined with FYM. However, RP applied with FYM and microbes gave highest values of crop growth parameters. The results of Chalk *et al*., (2002) also support our findings to investigate RP as a source of P in combination with FYM on yield of gram and wheat. The acidity created by FYM in form of CO_2 and organic acids helped in bringing P into available form. Addition of acid creating microbes like EM may further enhanced the process of P solubility from RP. The EM contains selected species of microorganisms including lactic acid bacteria, yeasts, smaller numbers of photosynthetic bacteria, actinomycetes, fermentative fungi and other types of organisms. All of these are mutually compatible with one another and can coexist in liquid culture. The lactic acid is a strong sterilizing compound enhancing decomposition of organic matter (Higa & Parr, 1994). The findings of Ahmad *et al*., (1997) support our results who concluded that the time of organic materials decomposition was significantly decreased by the application of EM. Hussain *et al*., (2000) reported the agronomic merits of EM in a rice-wheat cropping system. In all cases, the grain and straw yields with EM addition were higher than control. Similar supportive conclusions have been reported by Kishore (2000), XU *et al*., (2000) and Yamada & Xu (2001).

Conclusion

It could be concluded from the results of these experiments that application of rock phosphate with farm yard manure and effective microorganism have potential to improve crops yield and plants N and P uptake on sustainable basis as their effects are longer lived. This technology may effectively be adopted by the farmer's community as it is easy, economical and can help in improving the efficiency and availability of phosphorus in the area under investigations. Further research work is suggested in this area to explore phosphate reserves throughout the country and their effective utilization in better crops production in different agro-ecological zones of Pakistan with different treatments combinations.

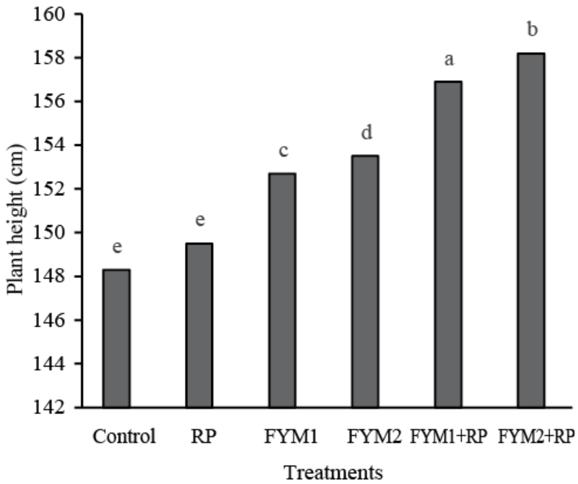

Fig. 1. Residual effect of RP and FYM applied with EM on height of sunflower plant.

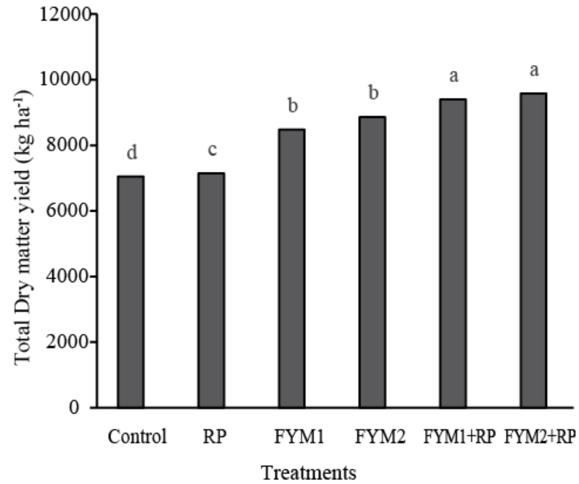

Fig. 4. Residual effect of RP and FYM applied with EM on total dry matter yield of sunflower.

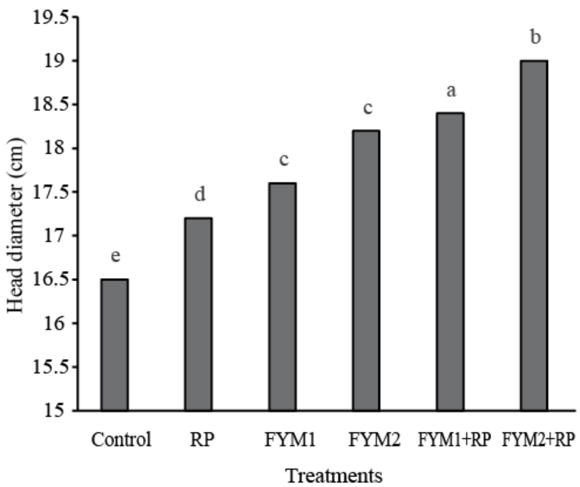

Fig. 2. Residual effect of RP and FYM applied with EM on head diameter of sunflower.

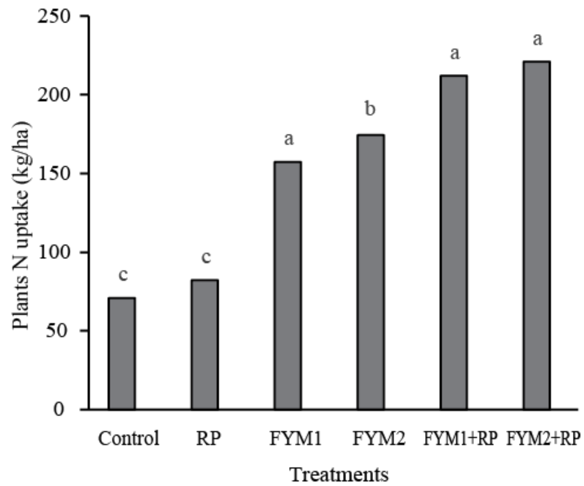

Fig. 5. Residual effect of RP and FYM applied with EM on plants N uptake of sunflower.

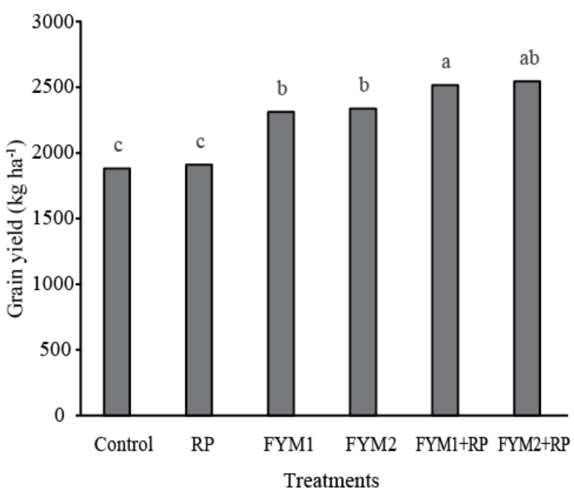

Fig. 3. Residual effect of RP and FYM applied with EM on grain yield of sunflower.

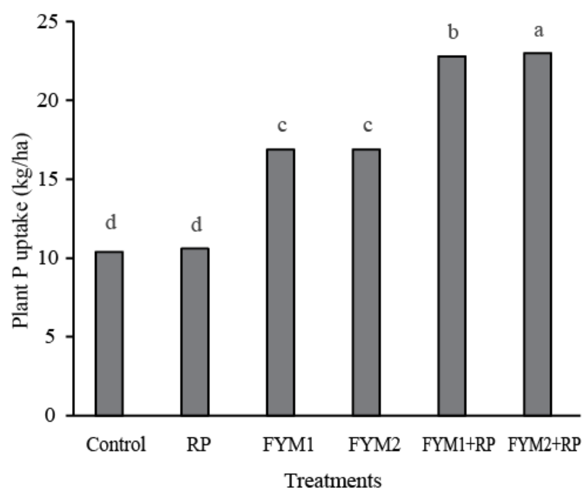

Fig. 6. Residual effect of RP and FYM applied with EM on plants P uptake of sunflower.

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