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Availability of Detergent, Biodegraded by *Bacillus subtilis*, to *Zea mays* Nutrition

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A common household detergent (Persil) was incubated with *Bacillus subtilis* for 7 days. Phosphorus in the filtrate was used as a base for a complete nutrient solution for maize; in comparison with a standard nutrient solution containing KH_2PO_4 as a phosphorus source. Incubated detergent in low doses (up to the equivalent of 0.35 and 0.2 mM P for shoot and root, respectively) was beneficial to maize and was even superior to KH_2PO_4; but higher doses imposed a harmful effect. Uptake of P by maize was slightly greater from KH_2PO_4 than from incubated detergent. Uptake of K and Ca was reduced, while that of Na was increased by increasing P level in the medium. The reduction in K concentration of plant tissues was more pronounced in case of KH_2PO_4- than that of incubated detergent-treated plants. Incubated detergent favored Ca transport to the shoot, compared with KH_2PO_4. Nitrogen uptake was enhanced in response to increasing P level and this was associated with enhancing assimilation of nitrate (decreasing NO_3^-/total N ratio) in shoot but retarding assimilation (increasing NO_3^-/total N ratio) in roots.

Keywords: *Bacillus subtilis*, Biodegradation, Detergent, Maize, Nutrients.

Abbreviations: RPR, RKR, RNaR and RCaR are the root P ratio, root K ratio, root Na ratio and root Ca ratio, respectively and refer to the proportions of the plant content of these elements allocated to the root.

The intensive cultivation practices used in modern agriculture impose high demand on the critical fertilizer elements nitrogen, phosphorus and potassium. The undue use of chemical fertilizers creates serious problems regarding the quality and safety measures of the crop and also led to pollution of soils and waters. Therefore, the trend today is to use non-conventional resources as fertilizers. This will perform several benefits: first it will save the environment from pollution and also save the costs of energy expenditure in producing chemical fertilizers, secondly it will permit recycling of the organic waste materials and using them as a valuable fertilizer which minimize the problem of accumulating organic wastes in the environment. Third it may produce a good quality produce or, in case of any potential hazards, these alternative fertilizers can be used for production of non-edible crops. The use of biofertilizers as a source of phosphorus has been reported to improve yield and quality of the medicinal plant *Carum copticum* and has been suggested as a valuable alternative to chemical fertilizers (Habibi and Talaei, 2014). Among the

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candidate organic wastes for this regime are poultry litter (Szogi *et al*., 2010) and composted municipal solid organic wastes (Leogrande *et al*., 2013).

Detergents and other household chemicals have being discharged into water bodies and ultimately to the soil in huge amounts daily. These chemicals pose a serious environmental problem since most of them are hazardous to soil biota, while others provide considerable amounts of nutrients and thus contribute to the problem of eutrophication (Ezemonye *et al*., 2006). The degree of toxicity differs according to the type of detergent.

Detergents are the major source of P input into water bodies through sewage and drainage systems. The major part of detergents comprises builders containing polyphosphate (sodium tripolyphosphate; Köhler, 2006). An environment friendly and effective synthetic builder is yet to be developed to replace the existing P-containing builders of detergents (Khan and Ansari, 2005). In addition to their use in industrial and domestic premises, surfactants are used to enhance penetration of herbicides in weed control in agriculture (Madhou *et al*., 2006), for dispersing oil spills at sea (Ezemonye *et al*., 2006) and in firefighting foams (Hartskeerl *et al*., 2004). Degradation of these chemicals is thus essential to save the environment. Furthermore, the P contained in these detergents can be utilized to promote growth of plants (Halliwell *et al*., 2001).

The role of microorganisms in solubilizing soil phosphates (Zhang *et al*., 2013) and degradation of different surfactants (Garland *et al*., 2004) has been reported. The present work was conducted to evaluate the importance of a common household detergent in Egypt (Persil), after incubation with *Bacillus subtilis*, as an alternative source of phosphorus to maize growth and nutrition compared with a standard full nutrient solution containing KH_2PO_4 as a P source.

Material and Methods

Biodegradation of detergent and preparation of nutrient solutions

A household detergent solution (2% persil) was incubated in a nutrient broth medium with *Bacillus subtilis* at 22ºC for 7 days and the mixture was centrifuged to get rid of bacteria. Preliminary studies revealed that by the seventh day of incubation, P content of the medium reached a maximum steady level. P content of the supernatant was used as the base for a nutrient solution for maize after supplementation with the lacking essential nutrients to simulate the standard KH_2PO_4-based nutrient solution. The 2% (w/v) detergent solution, after incubation with bacteria was found to contain the following elements (mM): P 4.07, K 0.33, Na 125.1, Ca 1.03, N zero and S 46.12.

Seedlings of *Zea mays* were grown with different levels of P (0.02, 0.2, 0.5 and 1 mM), supplied either as KH_2PO_4 or incubated detergent. In addition to the specified levels of P, nutrient solutions either KH_2PO_4- or detergent-based were adjusted to contain the following macronutrients (mM): N (as NO_3^-) 9, K 6, Ca 2, and Mg 1 and micronutrients (µM): Fe (as Fe-EDTA) 25, Mn 5, Cu 0.5, Zn 0.5, B 25, Na 50, Cl 50, Mo 0.25 and Co 0.1. Since detergent contained relatively high levels of Na and S, increasing P level, as detergent, was associated with increasing levels of Na and S in the nutrient solution. Therefore, Na_2SO_4 was used to adjust the levels of Na and S in the standard KH_2PO_4-based medium to a level similar to that of the detergent-based medium. Thus, with the increase in P level of the medium from 0.02 to 1 mM, Na level was simultaneously raised from 0.61 to 30.71 mM and that of S from 1.8 to 12.53 mM. In order to distinguish the effect of increasing P level of the medium from the effect of the concomitant increase in Na and S levels in nutrient solutions, an additional treatment was conducted in which P level (as KH_2PO_4) was set at 1 mM but with the normal levels of Na (0.05 mM) and S (1 mM). Statistical analysis revealed non-significant difference in plant growth between such treatment and the treatment with the highest level of P (1 mM) concomitant with high levels of Na (30.71 mM) and S (12.53 mM).

Growth conditions

Maize grains were sown in 10 cm-diameter plastic pots containing water-washed sand at a rate of 3 grains per pot. The pots were kept under controlled conditions (irradiance 350 µmol m^{-2} s^{-1} from white fluorescent tubes, temperature 25/15ºC with a 12/12 hr day and night periods, respectively, and relative humidity of 75% on average) and irrigated with 0.2 mM $CaSO_4$ for two weeks. The seedlings were then provided with a basic P-free nutrient solution for 15 days, during which seedlings were thinned gradually to one per pot. The P-free nutrient solution contained the following macronutrients (mM); K 5, Ca 2, N 9, Mg 1 and S 1 and the micronutrients (µM): Fe (as Fe-EDTA) 25, Mn 5, Cu 0.5, Zn 0.5, B 25, Na 50, Cl 50, Mo 0.25 and Co 0.1. After 15 days from application of the P-free nutrient solution, phosphorus treatment started; plants were divided into two groups: one receiving P as KH_2PO_4 and the other as incubated detergent; each with four levels of P (0.02, 0.2, 0.5 and 1 mM). Plants were harvested once after 25 days from the application of phosphorus treatment; by that time symptoms of detergent toxicity appeared. Plants were thoroughly washed from sand, blotted gently and fresh weights of shoots and roots were recorded. Dry weights were recorded after drying of fresh plant material at 80ºC for 48 hr. Dry plant material was ground into a fine powder prior to biochemical analysis.

The experiment was factorial with two factors and four replications in a completely randomized design. The factors were type of P source (KH_2PO_4 and incubated detergent) and level of phosphorus (four levels).

Chemical analysis of plant material

Estimation of nitrate and total nitrogen

Nitrate concentration of plant material was estimated according to the Brucine sulfate method of APHA (1992). For determination of total nitrogen, plant material was digested by the H_2SO_4–H_2O_2 digestion mixture using Se as a catalyst to convert nitrogen in plant material to NH_4^+ (Allen *et al*., 1986). Total nitrogen was determined as NH_4^+ by direct Nesslerization, according to the method of APHA (1992).

Determination of the major cations (potassium, sodium and calcium)

Potassium, sodium and calcium were determined in the clear extract resulting from H_2SO_4–H_2O_2 digestion by using a Jenway PFP7 Flame Photometer.

Determination of total phosphorus

Total phosphorus was determined in the extract according to the method of John (1970).

Chemical analysis of detergent

Mineral composition of detergent solution (the contents of N, P, K, Ca and Na) was assayed following the procedures used in the analysis of plant material. Sulfur content of detergent was assayed using the procedure of Harrison and Perry (1986).

Statistical analysis

Analysis of variance (ANOVA) and confidence limits about the mean were set by using SPSS program (version 11). Mean separation was performed using the Duncan multiple's range test at $p \leq 0.05$.

Results and Discussion

The results of analysis of variance of the effect of from and level of phosphorus on plant growth and mineral content of shoot and root are presented in Table 1.

Plant growth

Table 1 revadled greater effect of level of P on plant growth (higher F ratio and lower significance) than that of form of P. fresh weight of shoot and root of maize non-significantly increased by increasing P level of the medium from 0.02 to 1 mM as KH_2PO_4. In case of detergent, the increase was non-significant up to 0.2 mM P, with sharp decline as detergent level further increased up to 1 mM P; at which fresh weights of shoot and root were 49% and 77%, respectively, below their values at 0.02 mM P (Fig. 1). Dry weight, however, exhibited significant improvement in response to P nutrition. Fig. 2 shows that dry weight of maize significantly increased with the increase in P level of the medium as KH_2PO_4 with a tendency for steady values as P level exceeded 0.5 and 0.2 mM in case of shoot and root, respectively. By contrast, shoot dry weight progressively declined (by about 61%) as detergent level of the medium increased from 0.02 to 1 mM P. The inhibition in root dry weight by detergent amounted to about 77% over the range 0.2-1 mM P with a non-significant increase over the low detergent levels (0.02- 0.2 mM P).

Figure 2 shows also that incubated detergent was superior to KH_2PO_4, as a P source for maize, at the low levels (up to 0.35 and 0.2 mM for shoot and root, respectively), but exerted a marked toxic effect at higher doses, where dry weights of shoot and root of plants treated with detergent at 1 mM P were lowered by 55% and 79%, respectively, below those of KH_2PO_4-grown plants.

The toxic effect of high doses of detergent on seed germination and growth of maize has been reported by Heidari (2012). The differential effect of detergent relative to KH_2PO_4 can be attributed to substances exerting a growth promoting effect at low doses, but a toxic effect at high doses. These substances can be either specific ingredients in the detergent formula or certain compounds released as a result of bacterial growth. In this regard, Gajbhiye *et al*. (2003) demonstrated that phosphate solubilizing bacteria enhance fruit yield and increase nutrient uptake not only through release of phosphorus but also by producing growth promoting substances such as auxins, cytokinins and gibberellic acid as well as vitamins. Garland *et al*. (2004) using a nutrient film technique demonstrated differential response of wheat to 2different detergents

TABLE 1. The two-way ANOVA of growth and mineral content of shoot and root of *Zea mays* in response to varying the type and level of P showing the effects of main factors and their interaction.

Variable and source of variation	df	F	Sig.		Variable and source of variation	df	F	Sig.
Shoot fresh weight					**Root P**			
Type of P	1	3.93	0.059		Type of P	1	38.7	0.000
Level of P	3	1.58	0.220		Level of P	3	9.2	0.000
Type × Level	3	4.14	0.017		Type × Level	3	3.0	0.050
Root fresh weight					**Shoot Ca**			
Type of P	1	0.06	0.809		Type of P	1	18.9	0.000
Level of P	3	4.62	0.011		Level of P	3	8.7	0.000
Type × Level	3	7.20	0.001		Type × Level	3	1.3	0.297
Shoot dry weight					**Root Ca**			
Type of P	1	0.002	0.965		Type of P	1	4.2	0.050
Level of P	3	1.24	0.318		Level of P	3	4.0	0.019
Type × Level	3	7.04	0.001		Type × Level	3	10.0	0.000
Root dry weight					**Shoot K**			
Type of P	1	4.50	0.044		Type of P	1	12.0	0.002
Level of P	3	4.91	0.008		Level of P	3	25.9	0.000
Type × Level	3	5.20	0.007		Type × Level	3	10.0	0.000
R/Sh DW ratio					**Root K**			
Type of P	1	44.9	0.000		Type of P	1	1.33	0.260
Level of P	3	14.05	0.000		Level of P	3	4.48	0.012
Type × Level	3	4.75	0.010		Type × Level	3	8.36	0.000
Shoot nitrate					**Shoot Na**			
Type of P	1	17.9	0.000		Type of P	1	35.4	0.000
Level of P	3	97.5	0.000		Level of P	3	9.10	0.000
Type × Level	3	16.6	0.000		Type × Level	3	9.73	0.000
Root nitrate					**Root Na**			
Type of P	1	40.5	0.000		Type of P	1	15.0	0.000
Level of P	3	0.63	0.600		Level of P	3	14.1	0.000
Type × Level	3	0.20	0.893		Type × Level	3	0.40	0.754
Shoot N					**Shoot K/Na ratio**			
Type of P	1	0.23	0.636		Type of P	1	46.0	0.000
Level of P	3	22.4	0.000		Level of P	3	36.3	0.000
Type × Level	3	0.54	0.659		Type × Level	3	1.53	0.232
Root N					**Root K/Na ratio**			
Type of P	1	10.0	0.004		Type of P	1	1.78	0.195
Level of P	3	28.3	0.000		Level of P	3	9.41	0.000
Type × Level	3	4.6	0.011		Type × Level	3	3.23	0.040
Shoot P								
Type of P	1	1.79	0.193					
Level of P	3	6.63	0.002					
Type × Level	3	0.19	0.902					

where no growth reduction was observed in response to the anionic surfactant (sodium laureth sulfate), but biomass was reduced with the amphoteric (cocamidopropyl betaine) and the non-ionic (alcohol polyethoxylates) surfactants. In agreement with our findings, Poongodi and Sasikala (2013) reported that the lower concentration of a synthetic detergent (0.01%) enhanced growth and development of green gram, but higher concentrations ($\geq$ 0.02%) inhibited the growth and biochemical parameters of seedlings. In addition, application of P-rich organic wastes such as poultry manure significantly increased lettuce growth (Gunes *et al*., 2014).

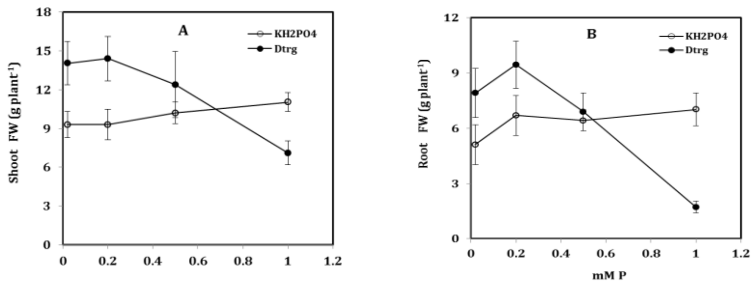

Fig. 1. Fresh weight of shoot (A) and root (B) of *Zea mays* grown with either KH_2PO_4 or incubated detergent (Persil) as P source. Each value is the mean of 4 replicates ± SE. $LSD_{(0.05)}$ = 4.23 for shoot fresh weight and 2.92 for root fresh weight.

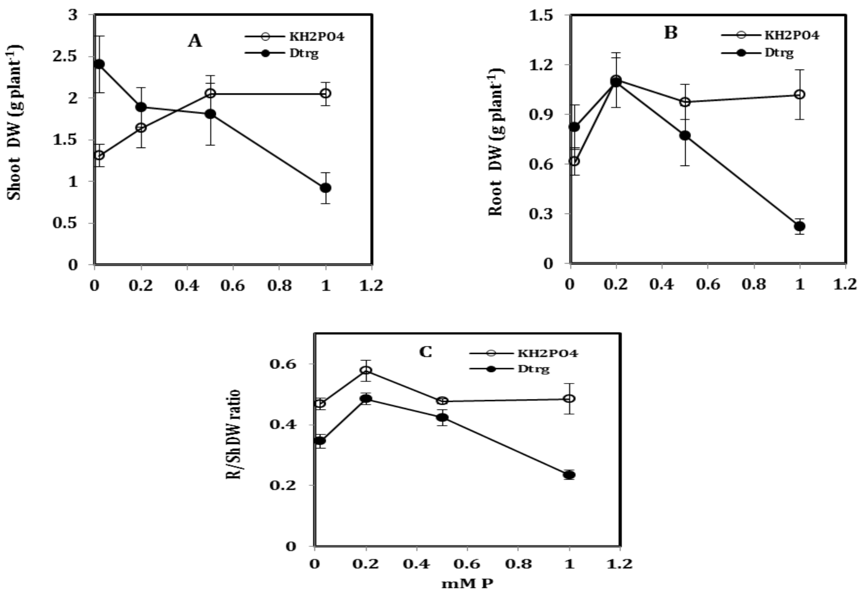

Fig. 2. Dry weight of shoot (A) and root (B) and root/shoot dry weight ratio (C) of *Zea mays* grown with either KH_2PO_4 or incubated detergent (Persil) as P source. Each value is the mean of 4 replicates ± SE. $LSD_{(0.05)}$ = 0.72 for shoot dry weight, 0.39 for root dry weight and 0.08 for R/Sh ratio.

In plants grown with KH_2PO_4, R/Sh dry weight ratio increased with the increase in P level of the medium up to 0.2 mM. This was the result of a relatively great promotion of root growth compared to shoot growth at low levels of P. At P levels higher than 0.2 mM, root growth approached a limit while shoot growth continued to increase progressively, resulting in low R/Sh ratio. A well-documented response to low P levels is the favored root growth relative to shoot growth and consequently increased R/Sh ratio (Reuter *et al.*, 1997; Bailey and Laidlaw, 1998). It has been claimed that under P deficiency proportionately more carbon and nutrient resources are partitioned to root growth than to shoot growth, in a way to facilitate better exploitation of the soil volume for P, causing an increase in the R/Sh ratio (Marschner, 1995). The increased R/Sh ratio by low levels of detergent (up to 0.2 mM P) can be attributed to a slight promotion of root growth, concurrently with marked retardation of shoot growth; while the decreased R/Sh ratio at high detergent doses can be due to greater retardation of root growth than of shoot growth. The low R/Sh ratio of detergent-treated plants compared to those fed with KH_2PO_4, particularly at the high doses of P might point to a more toxic effect of detergent on root growth of maize than on shoot growth.

Nitrate and total nitrogen

Treatments had in general highly significant effect on the concentration of nitrate and total nitrogen of plant tissue (Table 1).

Figure 3 shows that nitrate concentration of maize shoot progressively increased (by about 114%) as P level of the medium increased from 0.02 to 1 mM as KH_2PO_4; while in case of detergent the increase amounted to about 58% with the increase in P level from 0.02 to 0.2 mM, with almost no further effect at higher P levels. Nitrate concentration of maize roots, either fed with KH_2PO_4 or detergent, exhibited a non-significant reduction as P level of the medium increased from 0.02 to 1 mM. Nitrate concentration of the shoot and root of maize was significantly higher in detergent-treated than in KH_2PO_4-fed plants, particularly within the low and moderate levels of P.

Total nitrogen concentration of maize shoot, either treated with KH_2PO_4 or detergent, linearly increased with the increase in P level of the medium. In the root, N concentration of KH_2PO_4-grown plants exhibited a progressive decrease with the increase in P level of the medium up to 0.5 mM with relatively small reductions at higher P levels; but in detergent-treated roots nitrogen concentration attained a steady level over the range 0.02-0.5 mM P and the reduction was evident and significant (38.5%) as P level further increased from 0.5 to 1 mM. N concentration was higher (about 2 fold) in maize shoot than in root, and was comparable in the shoot of KH_2PO_4-fed and detergent-treated plants over the whole range of P levels used. In the root nitrogen concentration was comparable in KH_2PO_4- and detergent-treated plants at the low (<0.2 mM) and high (1 mM) P levels but markedly higher in detergent-treated plants than in KH_2PO_4-fed plants at the moderate levels of P (Fig. 3).

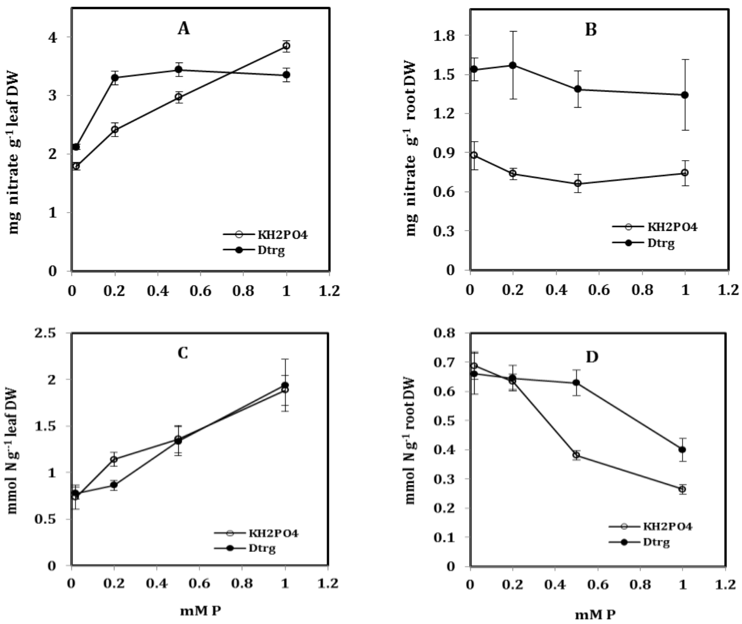

Fig. 3. Concentration of nitrate in the leaves (A) and root (B) and Total nitrogen (C) and (D) of *Zea mays* grown with either KH_2PO_4 or incubated detergent (Persil) as P source. Each value is the mean of 4 replicates ± SE. $LSD_{(0.05)}$ = 0.29 for leaf nitrate, 0.46 for root nitrate, 0.44 for shoot N and 0.15 for root N.

The increase in N concentration of the shoot was accompanied with smaller increases in nitrate concentration, *i.e.* decreasing NO_3^-/N ratio and this might point to increasing nitrate assimilation in the shoot with the increase in P level of the medium. In the root the low N concentration at high levels of P was accompanied with a non-significant decrease in nitrate concentration which means retarded nitrate assimilation at high P levels. The NO_3^-/N ratio in maize roots was higher in detergent- than KH_2PO_4-treated plants, but in shoot the ratio was comparable in the two treatments. It is well established that P nutrition affects uptake and assimilation of N by plants. Application of phosphorus-enriched poultry manure significantly increased nitrogen concentration of lettuce leaves (Gunes *et al*., 2014). In agreement with the present results, Rufty *et al*. (1993) demonstrated that P deficiency led to decreased rates of nitrate uptake and increased accumulation of absorbed NO_3^- in roots of soybean. With regard to the effect of detergent, the contents of total and insoluble nitrogen have been found to decrease in rice with detergent treatment (Nariaki *et al*., 1977).

Phosphorus and calcium

The effect of treatments was in general highly significant on the concentrations of P and Ca of plant tissue, particularly those of root (Table 1). P concentration of the shoot was non-significantly higher in KH_2PO_4- than detergent-treated maize; in both it progressively increased with the increase in P level of the medium (Fig. 4). P concentration of roots of KH_2PO_4- and detergent-treated plants increased with the increase in P level of the medium up to 0.2 mM with a tendency for saturation at higher doses of P. However, the increase was of greater magnitude in case of KH_2PO_4 than in case of detergent. P concentration of root was in general higher in KH_2PO_4- than in detergent-treated plants particularly at high levels of P.

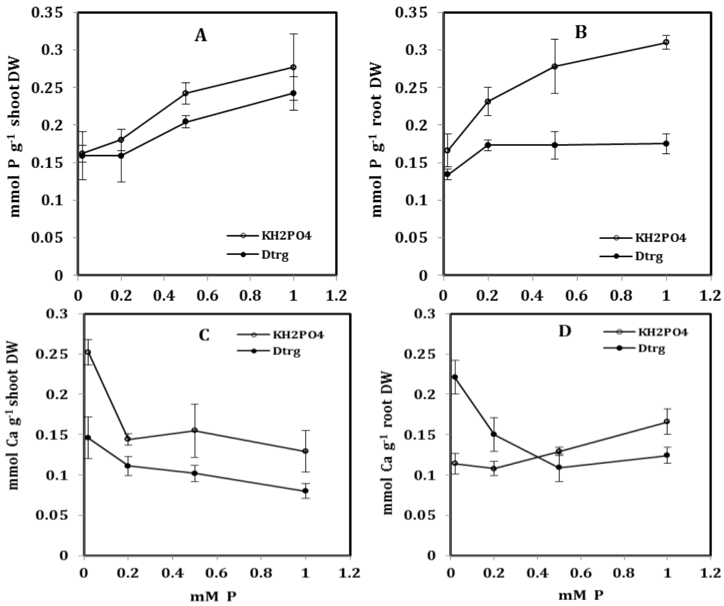

Fig. 4. Concentration of phosphorus in the shoot (A) and root (B) and calcium (C) and (D) of *Zea mays* grown with either KH_2PO_4 or incubated detergent (Persil) as P source. Each value is the mean of 4 replicates ± SE. . $LSD_{(0.05)}$ = 0.08 for shoot P, 0.05 for root P, 0.06 for shoot Ca and 0.05 for root Ca.

Uptake of P is expected to be inhibited in P-deficient plants and this inhibited uptake is accompanied with differential partitioning of P in favor of root (Reuter *et al*., 1997). Low-P plants had lower dry weights and lower P concentration than the high-P plants, and P was retranslocated from shoot to root in the P-deprived plants (Adalsteinsson and Jensen, 1989; Smith *et al*., 1990). However, this differential allocation of P in favor of root under P starvation was not evident in the present work. It seems that the lowest P level used in the present work (0.02 mM) was not too low to impose P stress on maize. Table 1 shows that root P ratio (RPR), which is a measure of allocation of plant P in favor of root, approached its maximum at 0.2 mM P not at the lowest level (0.02 mM). The results suggest that incubated detergent might represent a valuable source of P to maize particularly at low doses. In this respect, Gunes *et al.*, (2014) reported that application of phosphorus-rich organic wastes such as poultry manure increased phosphorus concentration of lettuce leaves.

Calcium concentration of the shoot of both KH_2PO_4- and detergent-treated plants was significantly reduced with the increase in P level of the medium up to 0.2 mM, with relatively small effects at higher P levels. However, the effect was more pronounced in KH_2PO_4-grown plants which also exhibited higher Ca levels, than in detergent-treated plants (Fig. 4). In the root, Ca concentration of KH_2PO_4-grown plants significantly increased as P level exceeded 0.2 mM; but in detergent-treated plants root Ca concentration was significantly reduced with the increase in P level of the medium up to 0.5 mM with steady low values at higher levels of P. Ca concentration was higher in shoot of KH_2PO_4-grown plants than in those treated with detergent, but in roots it was higher in detergent– treated plants within the low range of P (up to 0.5 mM) with the reverse being evident at higher levels of P.

The present findings suggest that increasing P level of the medium led to reduced uptake of Ca by maize and the effect was more evident in case of detergent then in case of KH_2PO_4. In case of KH_2PO_4, the reduced Ca uptake at high P levels was accompanied with reduced translocation to shoot high RCaR, (Table 1), but in case of detergent the reverse was found where RCaR decreased at high P levels which means enhanced Ca translocation to shoot. In tobacco, high levels of P in the nutrient medium were consistently related to low levels of Ca in plant tissues (Rhoads, 1974). Adalsteinsson and Jensen (1989) demonstrated that wheat cultivar with high P uptake efficiency had lower concentrations of Ca than the cultivar with low P uptake efficiency. Nevertheless, the reduced Ca uptake at high P levels found in the present work can be partially explained by the increasing Na^+ level with the increase of P level of the medium through the well-known Na^+-Ca^{+2} interactions of uptake (Reid and Smith, 2000; Tuna *et al*., 2007).

Potassium and sodium

The concentrations of K and Na of plant tissue, particularly those of shoot, were highly significantly affected by the form and level of P in the medium (Table 1). potassium concentration of shoot and root of KH_2PO_4-fed maize was significantly reduced with the increase in P level of the medium (Fig. 5). However, the pattern of reduction was different in case of shoot and root. In shoot, K concentration exhibited a relatively sharp reduction over the low P levels with a tendency towards a steady value as P level of the medium exceeded 0.5 mM. By contrast, K concentration of root was subjected to a small reduction over the low levels of P (up to 0.2 mM) with sharp reduction at higher P levels. In plants treated with detergent, K concentration of shoot exhibited a non-significant reduction while that of root exhibited a non-significant increase as P level of the medium increased up to 1 mM. Potassium concentration was higher in the shoot (about two times) than in the root and in the shoot of KH_2PO_4- than in detergent-fed plants particularly at low and moderate levels of P (up to 0.5 mM). Potassium concentration of the root was higher in KH_2PO_4- than in detergent-treated plants at low P levels (up to 0.4 mM) but was markedly higher in detergent- than KH_2PO_4-treated plants at higher P levels.

Sodium concentration of the shoot of KH_2PO_4-fed plants non-significantly increased while that of detergent-treated plants markedly increased (by about 250%) as P level of the medium increased from 0.02 to 1 mM (Fig. 5). Na concentration of the root of KH_2PO_4- and detergent-treated plants significantly increased with the increase in P level of the medium up to 0.2 mM, with a tendency for saturation at higher doses of P. Na^+ concentration was, in general, higher (about two fold) in root of maize than in the shoot and in detergent-treated plants than in those fed with KH_2PO_4 particularly at high P levels.

Figure 6 shows that K /Na ratio of shoots of either KH_2PO_4- or detergent-treated plants was significantly lowered with the increase in P level of the medium; however, in case of KH_2PO_4 the reduction was progressive up to 0.5 mM P with almost on effect at higher P levels. The reduction in K/Na ratio of root of KH_2PO_4-fed plants was progressive over the whole range of P used (0.02-1 mM) and was of greater magnitude compared to that of detergent-treated roots, in which the reduction was non-significant.

With the increase in P level of the medium as KH_2PO_4, K concentration was substantially reduced concomitantly with lesser promotion in plant biomass while in case of detergent the non-significant change in K concentration was associated with great reduction in biomass. This might signify that uptake of K by maize is retarded with the increase in P level of the medium, either as KH_2PO_4 or detergent. In addition, it seems that low and high levels of P favor K transport to shoot (low RKR) while moderate levels of P favor its retention by root (Table 1). The interaction between P and K has been demonstrated by Bailey and Laidlaw, (1998), where increasing P application lowered K concentration and likewise increasing K application decreased P concentration of white clover foliage. In wheat, Zhu *et al*. (2001) demonstrated that the cultivar with high P uptake efficiency had lower concentrations of K than the cultivar with low P uptake efficiency. In the present work, this effect can also be partially explained by the increasing Na level associating the increase in P level of the medium. Such Na^+-K^+ interactions has been demonstrated by Reid and Smith (2000) and Tuna *et al.* (2007).

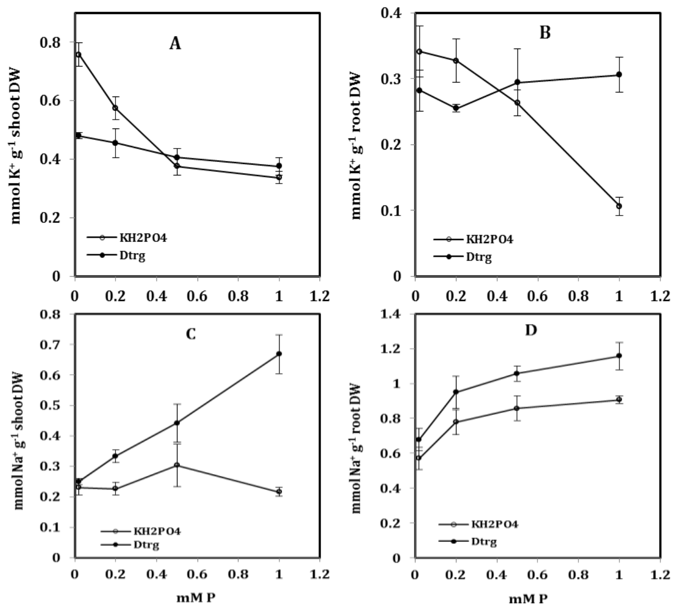

Fig. 5. Concentration of potassium in the shoot (A) and root (B) and sodium (C) and (D) of *Zea mays* grown with either KH_2PO_4 or incubated detergent (Persil) as P source. Each value is the mean of 4 replicates ± SE. $LSD_{(0.05)}$ = 0.09 for shoot K, 0.09 for root K, 0.12 for shoot Na and 0.19 for root Na.

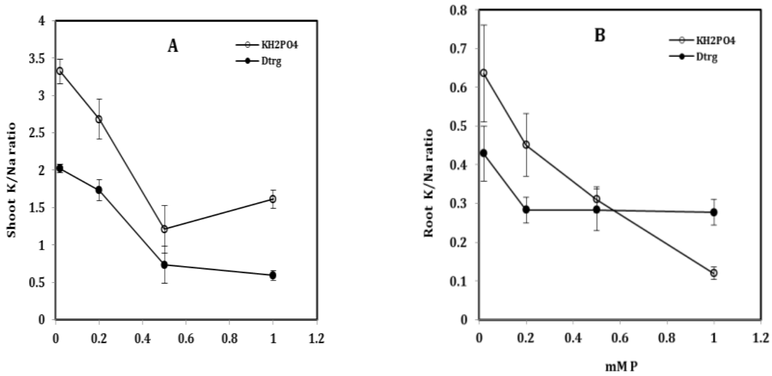

Fig. 6. K^+/Na^+ ratio in the shoot (A) and root (B) of *Zea mays* grown with either KH_2PO_4 or incubated detergent (Persil) as P source. Each value is the mean of 4 replicates ± SE. $LSD_{(0.05)}$ = 0.56 for shoot K/Na ratio and 0.19 for root K/Na ratio.

By contrast to K, uptake of Na by maize increased with the increase in P level of the medium, either as KH_2PO_4 or detergent. This seems reasonable since increasing detergent level was associated with increasing Na level as a result of the Na^+ contained in the detergent as builder and filler; meanwhile, composition of the KH_2PO_4 -based medium was adjusted to simulate that of the detergent-based medium by adding Na_2SO_4. In case of detergent the enhanced uptake of Na was associated with favorable transport of Na to shoot, resulting in progressive increase in Na concentration of shoot while that of root approached a limit, hence the observed low RNaR at high P levels (Table 1). This might partially explain the toxicity of detergent to maize. In most crop plants, sodium tends to be retained in roots to avoid buildup of high Na levels in shoot tissues where the delicate processes of metabolism occur. The loss of this favorite retention of Na by root might point to impairment of membranes integrity and loss of control of upward transport of ions to shoot (Khadri *et al*., 2007).

TABLE 2. Proportions of the plant contents of P, K, Na and Ca allocated to the root (RPR, RKR, RNaR and RCaR respectively) of *Zea mays* in response to P nutrition. P was supplied either as KH_2PO_4 or incubated detergent (Persil).

mM P	RPR	RKR	RNaR	RCaR
KH_2PO_4				
0.02	0.326	0.174	0.536	0.176
0.2	0.426	0.248	0.668	0.3000
0.5	0.355	0.252	0.575	0.283
1	0.358	0.134	0.675	0.389
Detergent				
0.02	0.226	0.167	0.478	0.342
0.2	0.347	0.215	0.633	0.397
0.5	0.265	0.235	0.503	0.305
1	0.147	0.161	0.289	0.267

In conclusion, household detergent (Persil) was assessed, after incubation with bacteria, as a potential alternative source of phosphorus to maize. Growth promotion was observed at low levels of detergent but higher levels were toxic. Incubated detergent had significant effects on mineral nutrition of maize compared to KH_2PO_4. Some bacteria such as *Bacillus subtilis* has the ability to degrade the detergent and the resulting filtrate can be used as a source of phosphorus for higher plants.

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ميسورية مكونات مسحوق غسيل محلل بيولوجيا بواسطة بكتيريا باسيلس سيتليس لتغذية نبات الذرة

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تم تحضين منظف منزلى شائع الاستعمال (برسيل) مع بكتيريا باسيلس سيتلس *Bacillus subtilis* لمدة سبعة أيام . استخدم الفوسفور المنطلق فى الراشح فى تحضير محلول مغذى متكامل لنبات الذرة وذلك مقارنة بمحلول اخر يحتوى على فوسفات البوتاسيوم ثنائية الهيدروجين كمصدر تقليدى للفوسفور . اتضح أن مستخلص المنظف المحضن بالبكتيريا كان مفيدا لنبات الذرة بل كان متفوقا على فوسفات البوتاسيوم ثنائية الهيدروجين فى الجرعات المنخفضة (حتى ما يكافىء 0,35 و0,2 ملمولار فى حالة المجموع الخضرى والجذور على التوالى) ولكن التركيزات العالية كان لها تأثير ضار. كان امتصاص نبات الذرة للفوسفور أعلى قليلا فى حالة فوسفات البوتاسيوم ثنائية الهيدروجين منه فى حالة المنظف المحضن . بزيادة تركيز الفسفورفى الوسط انخفض امتصاص النبات للبوتاسيوم والكالسيوم فى حين ازداد امتصاص الصوديوم وكان التأثير أكثر وضوحاً فى حالة البرسيل مقارنة بـفوسفات البوتاسيوم ثنائية الهيدروجين . بالإضافة إلى ذلك فقد زاد صعود الكالسيوم إلى الساق خاصة فى وجود البرسيل . أدت زيادة الفوسفور في الوسط إلي زيادة إمتصاص النيتروجين وزيادة تمثيل النترات (إنخفاض نسبة النترات/النيتروجين) فى المجموع الخضرى ولكن الى انخفاض تمثيل النترات فى الجذور .