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Research Article

Effect of Increasing Phosphorus Doses Application on Some Physical, Chemical and Biological Properties of Soil, Under Long-Term Experiment Conditions.

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ABSTRACT
Phosphorus (P) fertilizers are produced from rock phosphate (apatite); however, they are low-mobility in soil for plant nutrient absorption and uptake. In addition, the rock phosphate quantity is a limited source for future P fertilizer. At the same time, high phosphorus fertilization will cause environmental pollution (such as eutrophication in rivers). Also, a great proportion of applied P fertilizer remains in the soil, reducing the viable soil organisms. Therefore, the effect of different doses of P on some properties of soil (physical, chemical, and biological) is not entirely understood in the literature under long-term experiment conditions. Also, phosphorus fertilizer applications indirectly decrease the plant growth and yield. Under long-term experimental conditions, this research aims to understand the effect of increasing P doses on some physical, chemical and biological properties of the soil. The hypothesis to be tested is that under long-term field experiment conditions, increasing doses of phosphorus fertilizer negatively affect the soil properties. The field experiment was established in 1998 and has continued uninterruptedly to the present time under maize and wheat rotations. Four doses of P fertilizers were applied; such as 0, 50, 100 and 200 kg P_2O_5 ha^{-1} application with three replications. P2105 Maize (*Zea mays* L.) species seeds were sown in June 2022 and harvested in November 2022. At harvest, the soil samples were taken at 0-15 cm and 15-30 cm depth in each plot. Soil pH, EC and available P were analyzed as soil chemical properties. The number of mycorrhizal spores and Soil Organic Matter (by walkley-black method) were determined as soil biological properties. Furthermore, soil bulk density (BD), water stable aggregated (WSA) and mean weight diameter (MWD) were analyzed as soil physical properties.
Phosphorus application in increasing doses negatively affects the soil physical properties (such as WSA, MWD and BD) under long-term field experiment condition. The research finding showed that depending on increasing P doses application soil WSA and MWD were decreased but BD was increased. While depending on increasing P doses application soil organic carbon is increased, however, the numerical value of mycorrhizal spores and root colonization was decreased. The results are revealed that for sustainable and eco-friendly crop production, 50 and 100 kg P_2O_5 ha^{-1} P fertilizer can be used in maize production.
Keywords: Long-term field experiment, Soil organic carbon, Maize plant, Soil MWD, WSA, Phosphorus doses fertilizer

INTRODUCTION
Fertilizer usage is expected to carry on to grow with the growing food needs of the world population (Li et al., 2020). Phosphorus fertilizers are manufactured from rock phosphate (Green, 2015), and it has not a sustainable source and it can be finished next 50-100 years (Schnug & De Kok, 2016). Phosphorus deficiency is the restrictive factor for crop production on 40% of the arable worlds' land (Dey et al., 2021). Insufficient P fertilization leads to crop loss, while excessive P fertilization causes environmental problems such as eutrophication (Frossard et al., 2016). In addition, excessive P fertilization can also cause negative effects on the environment such as P heavy metal pollution (Kilgour et al., 2008) and salinity (Dey et al., 2021). Therefore, optimum P fertilization plays a significant role in protecting the environment as well as improving soil quality and fertility.

Land use has affected soil quality like physical, chemical and biological fertility (Bakhshandeh et al., 2019). Soil realize a significant environmental and ecological facility for food and survival life. In addition, soil health management has key role aimed at conservation of ecological production (Pahalvi et al., 2021). The main role of the soil has into yield enough nourishment and protected human health. Intensive input production such as intensive fertilization, tillage and excessive irrigation have an undesirable impact on soil health. One of them, chemical fertilizer has the greatest important role to improve soil fertility and yield. There are three types of available mineral(element) fertilizers like; N, P and K fertilizer (Pahalvi et al., 2021). The most used fertilizer after N fertilizers, which include so many potentially harmful chemicals, is P fertilizers. For example, P fertilizers mass-produced from apatite (rock sources) have contaminated by some heavy metals (like Cd, As and etc.) and radio-nuclides (De Kok & Schnug, 2008, Taylor et al., 2016). In addition, it is known chemical fertilizers increase soil salinity (Dey et al., 2021).

Amendment of soil through chemical (such as mineral fertilizers and plant protection preparations) powerfully impacts a variety of some soil properties such as soil activities of enzymes, nutrient content, Organic Carbon, pH, soil moisture and several others features (Prashar & Shah, 2016). Too much use of mineral/chemical fertilizers toughens the soil, lowers fertility of soil, pollutes environment (such as; water, soil and air) and depletes essential minerals and nutrıents out of the soil, thus causing an environmental hazard. The microbial activity in the cropping system is weakened by the use of chemical fertilizers. Continuous use of mineral fertilizers may modification soil pH, rise the chances of pest development, soil acidity and soil crusting, resulting in reduced organic matter, humus load, beneficial organisms, slower plant development, and even greenhouse gas emissions. They definitely affect the biodiversity of the soil, disrupting the well-being of the soil since it has been there for a long time (Pahalvi et al., 2021).

It is known that impact of manure and chemical fertilizers on some quality parameters of soil (Ozlu & Kumar, 2018). However, the impact of increasing P fertilizers, under long-term conditions as field experiment, on some physical, chemical, and biological properties of soil is not clear in the literature. That's why the purpose of the study is to understand the effect of increasing P concentrations on some physical, chemical and biological properties of the soil under long-term experimental conditions. The hypothesis to be tested is that in the long-term field experimental conditions, increasing concentrations of phosphorus fertilizer negatively affect soil properties.

MATERIALS AND METHODS

The field experiment has been established since 1998 on the soil Arık series, which is classified as typical Haploxererts, under maize and wheat rotations. Some physical and chemical properties of Arık soil series shown in Table 1. Four doses of P fertilizers were applied, such as 0, 50, 100, and 200 kg P_2O_5 ha^{-1}, (as P0, P50, P100 and P200), with tree replications before each term. P2105 Maize (*Zea mays* L.) species seeds were sown in June 2022 and harvested in November 2022. At harvest, the soil samples were taken at different depth as surface soil (as 0-15 cm) and subsurface soil (as 15–30 cm) in to each plot.

Soil pH and EC have defined 1:2.5 ratio of distilled water and available P were analyzed by Olsen (1954) method as soil chemical properties. The number of mycorrhizal spores was determined by Gerdemann and Nicolson (1963) and Soil Organic Matter (SOM) was analyzed via Walkley and Black (1934) method as soil biological properties. Furthermore, water stabile aggregate (WSA) and mean weight diameter (MWD) were analyzed by Kemper and Rosenau (1986) and soil bulk density (BD) was defined by Blake and Hartge (1986) as soil physical properties.

ANOVA statistical analysis was realized by JMP 8-pack program and the Less Significant Different (LSD) test was carried out. Moreover, the Origin 2022 application was used for the correlation matrix of variates.

Table 1. Some physical and chemical properties of Arık soil series (Turgut & Koca, 2019)

Soil Properties		Results
pH	(sat.)	7.63
EC	(mmhos cm^{-1})	0.06
Lime	(%)	27.2
Organic Matter	(%)	1.17
Texture (%)	Sand	17
	Silt	28
	Clay	55
Texture Classification	-	C
P_2O_5	(kg da^{-1})	7.11

RESULTS AND DISCUSSION

Soil Physical Properties

It is the physical properties of the soil that affect soil erosion, seed germination and root growth processes. Physical properties cause many chemical as well as biological processes, which can promote controlled by climate, land location, and land management (Jat et al., 2018).

In this work, MWD, WSA, and BD were investigated as physical soil properties. It was shown the impact of increasing doses of P applications on MWD and WSA in Figure 1 and Figure 2. They are shown that there was no statistically difference in MWD 0-15 cm and WSA at different soil depth ($P > 0.05$). Nevertheless, it is shown that statistically significant difference ($P<0.05$) on MWD at 15-30 cm depth as seen in Figure 1 and Table 2. In addition, it was shown that there was a negative correlation (from r = -0.43 to r = -0.83) between soil aggregation and soil available P content at different depths as seen in Figure 7. But on average, depend on increasing P fertilizer application, MWD and WSA are decrease. The P200 application reduced MWD by 26.4% surface soil and by 33.7% at subsurface soil compared to the P0 application. Furthermore, P200 application reduced WSA by 14.7% at 0-15 cm depth and by 14.6% at 15-30 cm compared to the P0 application. Intensive and heavy cultivation (like tillage, fertilizers and irrigation etc.) can disrupt soil aggregates, if those are not protected by the soil organic matter (Ozlu & Kumar, 2018, Ellis, 1971). It can cause a decrease in the WSA and MWD of the soil with the additives it contains. For example, Ozlu and Kumar (2018) reported that heavy chemical fertilizer application had lower aggregation (MWD and WSA) than control (without fertilizer) and organic fertilizers. Işık et al. (2019) investigated the impact of different organic and inorganic fertilizer applications on soil aggregation under long-term conditions. It seems that chemical fertilizers have the lowest aggregation and it was supports our research findings. Haynes and Naidu (1998) observed that continual application of inorganic fertilizer can diminish aggregate formation and stability by dispersing colloids and secondary soil particles and these findings lend credence to our investigation. Chemical fertilizers like TSP, which comprise additives, contain elements including Al, Ca, Fe, K, Na, Si, and high salinity (Shahsavani et al., 2017). In particular, Na can limit soil aggregation (García-Orenes et al., 2005).

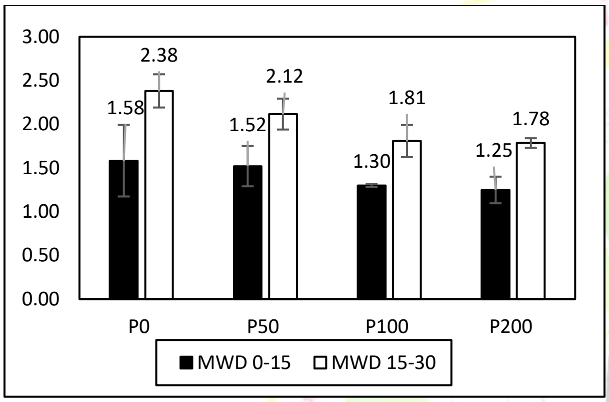

Figure 1. Effect of increasing phosphorus doses application on MWD in different depth.

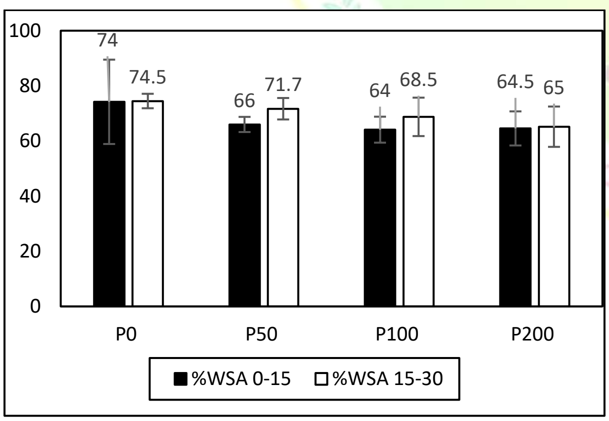

Figure 2. Effect of increasing phosphorus doses application on WSA (%) in different depth.

BD can be defined as the relationship between mass and volume of soil (de Oliveira et al., 2015) and it is usually expressed in g/cm^3. Typical values of the dry or BD of most soil differ between 1.1 and 1.6 g cm^3 (Rai et al., 2017). Soil BD determines the soil's porosity, available water capacity, infiltration, nutrient availability, rooting depth, root spread and microorganism activity (Indoria et al., 2020). Therefore, BD has an important place among soil physical properties. it was showed the effect of increasing phosphorus doses on BD in Figure 3. Increasing doses of P fertilization was not statistically make a difference (P>0.05) in soil BD, but it did increase the BD on average, under long term conditions. Moreover, it is shown that there was a statistically positive correlation (r = 0.83 and 0.58) between soil available P and BD in Figure 7. It has means that increasing doses of P fertilizers also increase soil BD.

Guo et al. (2016) research findings from their studies conducted between 2009 and 2014 show that chemical fertilizer applications increase BD compared to organic fertilizer applications. Their study partially supports our research findings. Moreover, Figure 3 shows that subsurface soil had a higher BD than surface soil depth. The decrease in BD over the years might be due to the increase in plant biomass, root biomass, the cementing effect of organic polysaccharides formed by the decomposition of OM through microbial activity. Pant and Ram (2018) reported that BD showed an increasing trend with increasing soil depth under respective treatments, and soil BD was lower in balanced and optimal fertilization treatments.

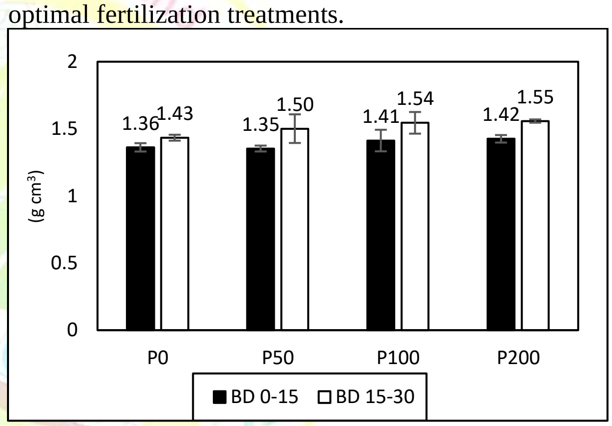

Figure 3. Effect of increasing phosphorus doses application on BD in different depth.

Table 2. Level of significance for effects of increasing phosphorus doses application on MWD, WSA, BD, P_2O_5, pH, EC, Organic Matter (O.M) and number of Mycorrhizal Spores (M. Spores) in different soil depth (0-15cm and 15-30cm)

MWD 0-15	MWD 15-30	WSA 0-15	WSA 15-30	BD 0-15	BD 15-30
NS	*	NS	NS	NS	NS
P_2O_5 0-15	P_2O_5 15-30	pH 0-15	pH 15-30	EC 0-15	EC 15-30
**	***	NS	NS	NS	NS
O.M 0-15	O.M 15-30	M. Spores 0-15	M. Spores 15-30		
NS	**	NS	NS		

NS means not significant. *, ** and *** respectively show significant level at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$.

Soil Chemical Properties

Soil chemical properties are essential to plant nutrition. Soil chemical properties were pH, TC, TN, cation exchangeable capacity (like Ca, Mg, K and Na), available P (Ahmadpour et al., 2015). One of them, P, is a factor that negatively affects 40% of agricultural production due to its deficiency (Balemi & Negisho, 2012). Inadequate P fertilization can lead to crop losses, whereas too much P fertilization can causes environmental problems such as eutrophication (Frossard et al., 2016). For that reason, optimum P doses fertilizers is vital for economic, sustainable and eco-friendly plant production.

It is presented that the impact of increasing P doses on soil available P at different depth as seen Figure 4. Increasing doses of P fertilization made a statistically significant difference (at surface soil P<0.01 and at subsurface soil P<0.001) at both depths as seen in Table 2. It is expected that the soil available P concentration will increase depending on the application of increasing doses of P. There are so many studies about how the soil P concentration will increase depending on increasing doses of P (Akpinar & Ortas, 2023, Işık et al., 2020a, Zhang et al., 2004). Additionally, available P concentration in soil surface is greater than subsurface soil. The higher P content of the surface soil than the subsurface may be the result of stubble west (like root etc.) or P fertilizer application close to the surface.

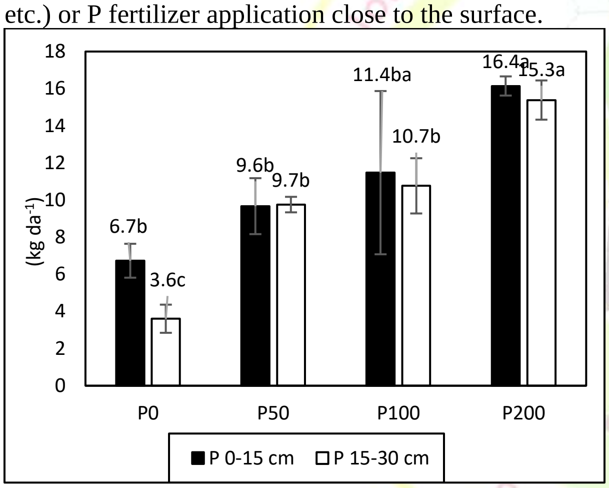

Figure 4. Effect of increasing phosphorus doses application on soil available P in different depth

Soil pH has an important impact on microbial activity and the biogeochemical processes where they participate. In general, the fungal community has an ideal environment in acidic conditions, whereas the bacterial community has decreased, thus the processes accomplish by some microorganisms can be negatively affected (de Melo et al., 2018). Furthermore, soil pH has also effected the nutrition (like Zn, Fe, P and others) uptake (Kacar & Katkat, 2015). It was seen that impact of various phosphorus doses application on soil pH and EC in Table 3. In Table 3, there was no statistical significant different (P>0.05) as soil pH in different depth. rSoil pH was not one of the easily changeable properties of the soil (Özbek et al., 1993). Also, there was no statistical significant different (P>0.05) as soil EC in different depth at Table 3. However, depend on increasing dose P fertilizers also soil EC increase on average. Chemical fertilizer application can cause the soil EC to increase (Citak & Sonmez, 2011).

Table 3. Effect of increasing phosphorus doses application on soil pH and EC (µS cm^{-1}) in different depth.

Applications	pH 0-15 cm	pH 15-30 cm	EC 0-15 cm	EC 15-30 cm
P0	7.65±0.3	7.62±0.0	244±8	187±12
P50	7.51±0.2	7.62±0.1	243±3	197±1
P100	7.60±0.3	7.58±0.0	247±35	201±28
P200	7.56±0.1	7.59±0.1	264±18	202±0
	P>0.05	*P>0.05*	*P>0.05*	*P>0.05*

Soil Biological Properties

Mycorrhizae are a nearly worldwide terrestrial mutualism between plant roots and certain fungi of soil, the oldest fossil evidence about mycorrhiza nearly 400 My ago (Egerton-Warburton et al., 2005). Several study reports revealed that mycorrhizal fungi may increase water and nutrient absorption in addition to increasing the bioavailability of phosphorus (P) to the host plant and improving growth. For the purpose of improved physical, chemical, and biological properties of soils, plant and mycorrhizal interaction is an essential association within rhizosphere (Johnson & Jansa, 2017). It is shown that effect of increasing P doses on the mycorrhizal number of spores in different depth in Figure 5. There weren't significant differences in the impact of increasing quantities of P application on the amount of spores. In addition, there was a negative correlation (r = -0.61 and -0.33) between mycorrhizal spores and soil available P concentration in different depths as seen in Figure 7. Higher amount of P in the plant tissue decreases the number of spores production and secondary external hyphae (Grant et al., 2005). Furthermore, soil pH can negatively affect the number of spores (Qin et al., 2020). It is known that fungi (like mycorrhiza) can usually live at low pH (Davison et al., 2021).

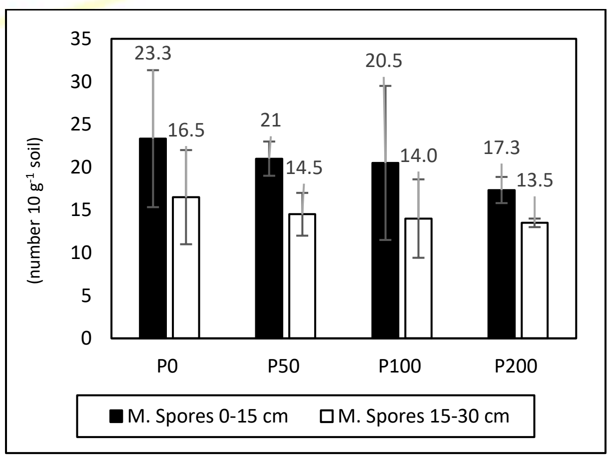

Figure 5. Effect of increasing phosphorus doses application on mycorrhizal number of spores in different depth

organic fraction (Bernoux & Cerri, 2005). Soil OM has a vital role for soil production, fertility and the carbon cycle (Simpson & Simpson, 2017), and it also improves infiltration, porosity, nutrition, and microbial activity (Güzel et al., 2002, Özbek et al., 1993). It was presented that effect of increasing P doses application on soil organic matter (%) in Figure 6. There was no statistical difference at surface soil (P>0.05) nonetheless, there was statistical significant different at subsurface soil (P<0.01) as seen Table 2. Average OM increases with increasing doses of P. The P200 dose has the highest OM ratio (%) compared to P0. The P200 application increased soil OM content by 11.7% at 0-15 cm depth and by 11.9% at 15-30 cm depth compared to P0 application. In addition, it is shown that positive correlation in the middle of available P and OM in different depths (Figure 7). Stubble residues (He et al., 2015), microbial activity and root secretions (like alcohol, enzyme activity, and phenol compounds) may have increased soil OM (Van Aken, 2011, Işık et al., 2020b). In addition, there is a positive correlation among soil P concentration and subsoil %OM in Figure 7.

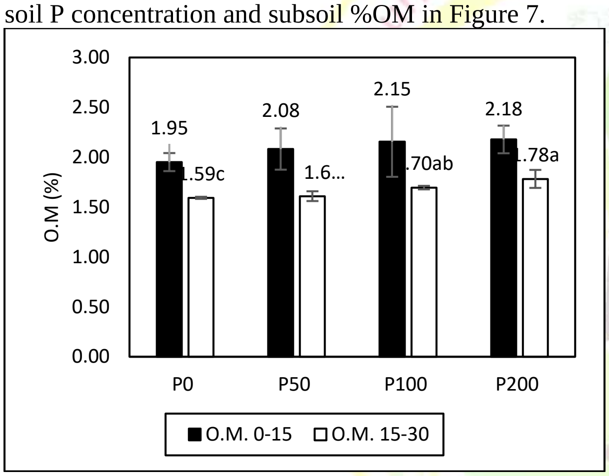

Figure 6. Effect of increasing phosphorus doses application on soil organic matter in different depth

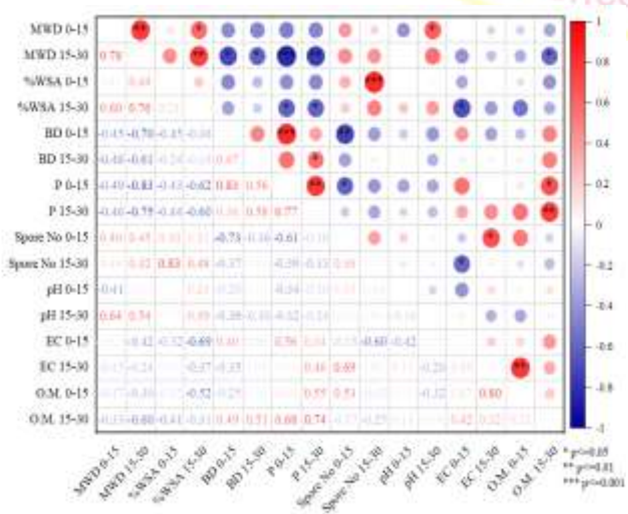

Figure 7. Correlation matrix of soil variates.

CONCLUSION

The physical qualities of the soil (such as MWD, WSA, and BD) were negatively impacted by P fertilization at escalating doses under long-term experiment circumstances initially. Mycorrhizal spore counts were reduced and OM was enhanced as P fertilizer treatment doses were raised. While soil pH and EC characteristics remained mostly unchanged, soil P content increased as P doses were raised. The health of the soil and sustainable production are not improved by excessive chemical P fertilization, which can also have a destructive effect on the soil physical and partially biological qualities.

CONFLICT OF INTEREST

The author here declares that there is no conflict of interest in the publication of this article.

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