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Full Length Article

Co-Application of Farmyard Manure and Gypsum Improves Yield and Quality of Peanut (*Arachis hypogaea*) under Rainfed Conditions

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Abstract

Peanut (*Arachis hypogaea* L.) is the common cash crop of the rainfed areas. Appropriate management practices are very important to get better yield of peanut in sandy loam soil. A field study was carried out during the growing seasons of 2018 and 2019 to evaluate the effect of poultry manure (PM) (37.1 t ha^{-1}), farmyard manure (FYM) (49.4 t ha^{-1}), gypsum (GYP) (2.5 t ha^{-1}), liquid humic acid (HA) (49.4 L ha^{-1}) and co-application of GYP (1.2 t ha^{-1}) and FYM (24.7 t ha^{-1}) on peanut yield, quality and soil physical properties. Application of FYM, PM, HA and GYP (alone or in combination) significantly improved peanut yield, quality and soil physical properties. The combined application of GYP and FYM proved most effective ($P \leq 0.05$) in improving the peanut yield (no. of pods per plant, 100 seed weight etc), quality (crude protein and oil content) and soil physical properties (moisture percentage, infiltration rate and bulk density). The combined application of GYP and FYM increased the pods yield by 67 and 65% during 2018 and 2019, respectively than control. Crude proteins (21%) and oil contents (9.0%) were also substantially increased in the combined application. Moreover, the combined application of GYP and FYM significantly retained the soil moisture and reduced bulk density of soil. Present findings suggest that integrated use of FYM and GYP under field conditions could improve the crop productivity, crude protein, oil contents, moisture percentage, and reduce the bulk density of soil thus improving overall soil health.

Key words: Farm yard manure; Poultry manure; Gypsum; Humic acid; Peanut; Soil health

Introduction

Peanut (*Arachis hypogaea* L.) also known as the “king of oilseed” belongs to the family fabaceae as one of the world’s largest legume crop, ranks 2nd after soybean (*Glycine max* L.) (Shad *et al.* 2009) and can be cultivated across diverse climatic conditions (Kiniry *et al.* 2005). It is ranked 13th among the food crops and 4th among oilseed crop, and its haulm is used as animal feed (El-Akhal *et al.* 2013; Meena *et al.* 2016).

The low agricultural productivity of peanut is attributed to various factors including low quality of seed, imbalanced fertilizer use, drought, unavailability of irrigation water, seasonal variation in rainfall patterns, and infertile soils due to low organic matter (Ashfaq *et al.* 2003; Hussainy and Arivukodi 2019). As compared to other field crops, the cultivation of oil seed crops such as soybean, sunflower (*Helianthus annuus* L.), and peanut have not received much attention (Kephe *et al.* 2020). The oil contents of peanuts are higher than soybean, hence considering peanuts oil quality, its cultivation could be considered as an alternative (Wang *et al.* 2012). Increase in area under cultivation and yield of peanut is possible through quality seed, proper soil management practices and efficient nutrient management such as integrated use of organic and inorganic nutrients (Mahrous *et al.* 2015).

Among the amendments, organic manures improve soil fertility, water-holding capacity, and overall biomass of plant growth promoting microbes (Esmaeilian *et al.* 2012). Moreover, organic manures are being preferred over inorganic fertilizers in improving soil physical properties (Busscher *et al.* 2010). Peanut as a potential oilseed crop requires an adequate amount of nutrients especially phosphorus (P) and potassium (K). Proper nutrient management is the key factor among the best agronomic practices, supporting sustainable crop production for longer run without disturbing soil fertility and health (Sarkar *et al.* 2017; Kumar *et al.* 2018). There is a direct relation between

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the crop productivity and fertilizer usage. Approximately 50% of the increased productivity is attributed to the fertilizer use in the last decades (Erisman *et al.* 2008). Mostly farmers prefer mineral fertilizers over the organic manures to increase crop productivity without considering the soil and environmental health (Abdelhafez *et al.* 2012). The long-term use of mineral fertilizers can deteriorate soil health resulting in soil acidification, poor soil aggregation, and micronutrients deficiency (Karmakar *et al.* 2020).

It is a fact that the minimal use of chemical fertilizers and increased use of organic amendments can positively affect the physico-chemical properties of soil, by influencing pH, infiltration rate, and water holding capacity and serving as potential nutrients sources (Mahmoodabadi *et al.* 2010; Sawrup 2010; Cesarano *et al.* 2017). Due to a number of benefits, the use of soil organic fertilizers is being widely accepted (Uygur and Karabatak 2009; Urra *et al.* 2019). Furthermore, the combined use of organic and inorganic fertilizers could be an appropriate and efficient practice for increasing the efficiency of the chemical fertilizer improving the soil health and productivity (Schoebitz and Vidal 2016). Therefore, the present study was conducted with the aim to investigate the effect of co-application of organic and inorganic fertilizers on yield, quality of peanut and physical properties of soil under rain-fed conditions. We hypothesized that the integrated use of FYM and GYP under field conditions may improve the yield, protein, oil contents in peanut as well as moiture contents and reduce the bulk density of soil.

Materials and Methods

Experimental setup and treatments

A field experiment was conducted at Barani Agricultural Research Institute, Chakwal (32° 56' 0" N, 72° 42' 0" E) to evaluate the effect of organic and inorganic amendments on soil physical properties, peanuts yield and quality under rain-fed conditions (average rainfall ≤ 600 mm) during the years 2018 and 2019. Two months prior to sowing, poultry manure (PM) (37.1 t ha^{-1}), farmyard manure (FYM) (49.4 t ha^{-1}), gypsum (GYP) (2.5 t ha^{-1}), liquid humic acid (HA) (49.4 L ha^{-1}) and GYP (1.2 t ha^{-1}) + FYM (24.7 t ha^{-1}) (in 1:1) were applied in the respective plots (5 m × 5 m) following randomized complete block design (RCBD) replicated thrice. Peanuts seeds of variety BARI-2011 were sown at the rate of 74 kg ha^{-1} using drill during last week of April and crop was harvested in the 1st week of November each year. Plant density was maintained 30 days after sowing, and all other parameters were recorded after 180 days of sowing. Recommended doses of nitrogen (N), phosphorus (P) and potassium (K) were applied at the rate of 20, 80, and 60 kg ha^{-1} using di-ammonium phosphate (DAP), single super phosphate (SSP) and sulfate of potash (SOP) prior to sowing during field preparation.

Physico-chemical properties of soil

Two months prior to sowing during both years, a composite sample of sieved soil (2 mm) was used to analyze the soil physico-chemical properties and nutrients (*i.e.*, N, P and K) (Table 1). The soil texture was determined by hydrometer method (Bouyoucos 1951). While to determine soil moisture content (%), gravimetric method was followed (Reynolds 1970). Soil electrical conductivity (EC) was measured using EC meter (S505141 EC Meter, Sper Scientific, USA) while, pH by the pH meter (HI8520 pH Meter, Hanna Instruments, Italy). The concentrations of Ca^{+2} and Mg^{+2} in soils were determined using EDTA method (Estefan *et al.* 2013). Organic matter content in the soil was determined following Walkley Black method (Walkley and Black 1934). While, contents of N, P and K in the soils were determined *via* Kjeldhal apparatus (Bremner 1960), spectrophotometer and flame photometer (Stanford and English 1949), respectively, following standard protocols.

In order to evaluate the effect of different organic and inorganic amendments on soil physical properties, bulk density, infiltrations rate, and moisture percentage of soils were determined after harvesting of crop each year. To determine soil bulk density, undisturbed soil cores having 5 cm internal diameter and with 6 cm height were drawn from 0–15 cm and 15–30 cm using a core sampler. After collection, samples were oven dried at 105°C until constant weight, and bulk density (Mg m^{-3}) was calculated by dividing the weight of oven dried soil samples to the volume of core used (Veihmeyer and Hendrickson 1948). While, ring infiltrometers of large diameter were used to measure infiltration rate (Johnson 1963). To assess moisture percentage, the gravimetric method was followed by weighing fresh and oven dried samples. (Topp and Ferre 2002).

Nutrient analyses of poultry and farm yard manure

For nutrient analyses of PM and FYM, 0.5 g sample of each manure was digested with sulfuric acid (H_2SO_4) and hydrogen peroxide (H_2O_2) following method described by (Wolf 1982). This digestion mixture was heated till the appearance of clear solution and N, P and K contents were measured using Kjeldahl, spectrophotometer and flame photometer, respectively (Table 2).

Peanut yield and quality attributes

The plant density was recorded on 30th day of sowing each year. For number of pods $plant^{-1}$, 100-grain weight and pods yield, peanut crop was harvested after 180 d of sowing both in 2018 and 2019. To determine the effect of amendments on quality of peanut, the crude protein and oil contents were analyzed from the harvested peanut seeds. Peanut seeds were initially dried to a constant weight at 50°C. After de-shelling, seeds were crushed and ground to a fine powder.

Table 1: Physicochemical characteristics of soils used in this study prior to sowing during 2018 and 2019

Parameters	2018	2019
Texture	Sandy clay loam (sand 51.2% clay 29.8% and silt 19%)	Sandy clay loam (sand 52% clay 28.5% and silt 19.5%)
Moisture (%)	8.75 ± 0.85	10.7 ± 1.10
pH	7.85 ± 0.20	7.60 ± 0.27
ECe (dSm^{-1})	1.85 ± 0.07	1.91 ± 0.08
CEC ($cmol_c\ kg^{-1}$)	8.60 ± 1.05	11.1 ± 1.70
Soluble Ca^{2+} + Mg^{2+} ($mmol_c\ L^{-1}$)	7.15 ± 0.60	7.80 ± 0.65
Organic matter (%)	0.50 ± 0.03	0.57 ± 0.03
$CaCO_3$ (%)	4.60 ± 0.19	4.90 ± 0.16
Total nitrogen (%)	0.47 ± 0.02	0.54 ± 0.01
Available phosphorus (mg kg^{-1})	4.58 ± 0.10	5.66 ± 0.15
Available potassium (mg kg^{-1})	130 ± 14.9	141 ± 15.5
Bulk density (Mg m^{-3}) (0-15 cm)	1.42 ± 0.02	1.41 ± 0.02
Bulk density (Mg m^{-3}) (15-30 cm)	1.45 ± 0.03	1.43 ± 0.03
Infiltration rate (mm h^{-1})	19.3 ± 1.75	18.7 ± 1.30

ECe = Electrical conductivity; CEC = Cation exchange capacity; $CaCO_3$ = Calcium carbonate
Values represent means (n=3) ± standard errors

Table 2: Nutrients in poultry and farm yard manures used during 2018 and 2019

Parameters	2018		2019	
	PM	FYM	PM	FYM
Nitrogen (%)	2.80 ± 0.13	0.53 ± 0.06	2.75 ± 0.11	0.51 ± 0.05
Phosphorus (%)	1.40 ± 0.08	0.21 ± 0.02	1.42 ± 0.09	0.23 ± 0.03
Potassium (%)	1.60 ± 0.09	0.60 ± 0.04	1.56 ± 0.08	0.65 ± 0.05

PM = Poultry manure; FYM = Farm yard manure
Values represent means (n=3) ± standard errors

To measure crude protein content, total N content was determined using a digestion and distillation system following micro-Kjeldahl method (Sweeney and Rexroad 1987), and then crude protein content was calculated by multiplying N content by a factor of 6.25 (Jones 1931). While, for the oil content, Soxhlet apparatus (Soxtec 2050, FOSS, Denmark) was used (Niu *et al.* 2014).

Statistical analysis

The analysis of variance was used to estimate variations from mean (n=3) values by standard errors. Means were compared at 5% level of significance by applying LSD test using Statistix 8.1 (Snedecor and Cochran 1980).

Results

Effects on yield attributes

The results showed that organic and inorganic amendments did not reveal great differences in plant density among the applied treatments; however, the combined application of GYP and FYM significantly improved the plant density by 18% than control, while, 13% higher plant density was observed by the individual application of HA as compared to control (Fig. 1a).

The application of organic and inorganic fertilizers had a positive influence on the number of pods of peanut as compared to control during both years 2018 and 2019 (Fig. 1b). Approximately, 9.6, 29, 17 and 9.8% more number of pods per plant were observed with application of PM, FYM, GYP, and HA, respectively than control treatment (Fig. 1b). The combined application of GYP and FYM had 57% higher number of pods than control.

Application of PM, FYM, GYP, and HA had 16, 17, 13 and 14% higher 100-grain weight, than control treatment respectively (Fig. 1c). The combined use of GYP and FYM increased 25% 100-grain weight as compared to control treatment (Fig. 1c). For pods yield, 37, 42, 27 and 17% higher yield values of peanut were observed on applying PM, FYM, GYP, and HA, than control respectively (Fig. 1d). While on combined application of GYP and FYM, there was an increase of 67% in peanut yield than control. Briefly, the application of organic and inorganic fertilizers had significantly ($P \leq 0.05$) improved the yield of peanut as compared to control.

Effects on quality attributes

The co-application of organic and inorganic fertilizers significantly ($P \leq 0.05$) affected the crude protein and oil content of peanut as compared to control during both years (Fig. 2a and b). Results showed that 13, 7.8, 6.7 and 12% higher crude protein contents were observed with PM, FYM, GYP, and HA, than control respectively (Fig. 2a). The combined application of GYP and FYM had 22% higher crude protein content than control. Similarly, 3.6, 2.7, 2.4 and 4.5% higher oil contents were observed on applying PM, FYM, GYP, and HA, than control respectively (Fig. 2b). Using GYP in combination with FYM had 8.5% higher oil contents than control.

Effects on soil properties

Co-application of organic and inorganic fertilizers improved

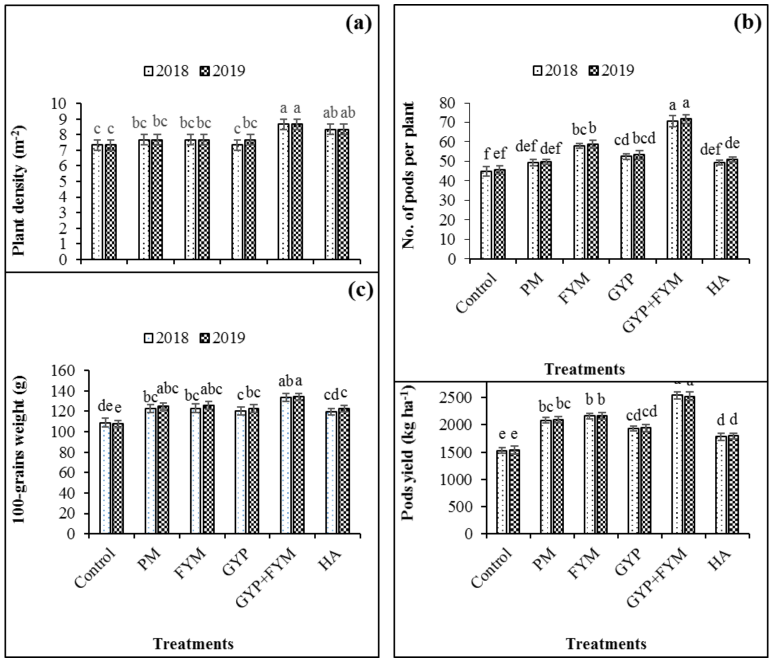

Fig. 1: Effects of organic and inorganic amendments on plants density **(a)**, no. of pods per plant **(b)**, 100-grains weight **(c)** and pods yield **(d)** of peanut grown during 2018 and 2019. Plant density was noticed after 30 d of sowing, and all other values shown here were taken after 180 d of sowing. Columns and bars represent means and standard errors, respectively of triplicate values. Means having different letters differ significantly according to LSD test at $P \leq 0.05$. (*Control*, treatment without any amendments; *PM*, treatment with only poultry manure; *FYM*, treatment with only farm yard manure; *GYP*, treatment with only gypsum; *GYP + FYM*, treatment with both gypsum and farm yard manure; *HA*, treatment with only liquid humic acid)

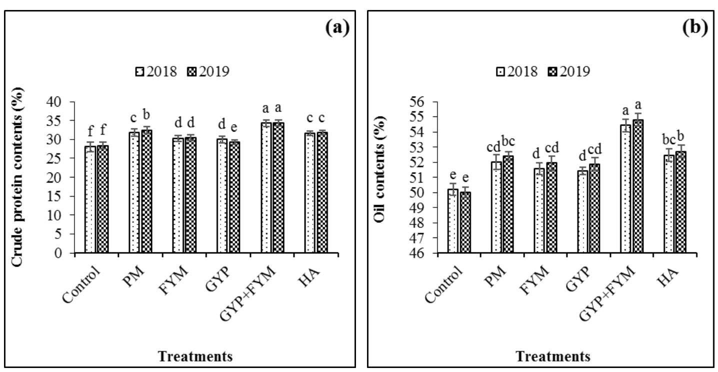

Fig. 2: Effect of organic and inorganic amendments on crude protein contents **(a)** and oil contents **(b)** of peanut grown during 2018 and 2019. All the values shown here were taken after 180 d of sowing. Columns and bars represent means and standard errors, respectively of triplicate values. Means having different letters differ significantly according to LSD test at $P \leq 0.05$

soil physical properties including soil bulk density, infiltration rate and moisture percentage (Table 3). Approximately 4.7, 4.8, 3.8 and 4.3% reduced bulk density (0–15 cm) than control was observed by the application of PM, FYM, GYP, and HA, respectively (Table 3). While, 8.7% reduced bulk density was observed on combined application of GYP and FYM. Almost similar trend was observed for the bulk density of the subsoil (15–30 cm). On the other hand, 8.9, 8.3, 7.9 and 1.9% reduced rate of water infiltration was observed on applying PM, FYM, GYP and HA, as compared to control respectively (Table 3). While on integrated use of GYP and FYM, 10% decreased water infiltration rate was observed as compared to control. In case of moisture content, 55, 48, 43 and 17% increased moisture content as compared to control was observed by the application of PM, FYM, GYP, and HA, respectively (Table 3), while combined application of GYP and FYM, increased 88% moisture content as compared to control was observed. Briefly, addition of each organic or inorganic amendment improved the soil physical properties but the effect of co-application of GYP and FYM was most significant.

Table 3: Effects of organic and inorganic amendments on soil physical properties during 2018 and 2019

Treatments	Bulk density (Mg m^{-3})				Infiltration rate (mm h^{-1})		Moisture percentage (%)	
	2018		2019		2018	2019	2018	2019
	(0-15 cm)	(15-30 cm)	(0-15 cm)	(15-30 cm)				
Control	1.41 ± 0.01^{a}	1.45 ± 0.01^{a}	1.40 ± 0.01^{a}	1.44 ± 0.01^{a}	18.67 ± 1.16^{a}	18.07 ± 1.21^{bc}	5.20 ± 0.20^{d}	4.20 ± 0.16^{e}
PM	1.35 ± 0.01^{bc}	1.38 ± 0.01^{bcd}	1.33 ± 0.02^{cd}	1.37 ± 0.01^{cd}	17.00 ± 0.98^{de}	17.00 ± 1.15^{de}	6.50 ± 0.24^{b}	6.81 ± 0.33^{b}
FYM	1.35 ± 0.01^{bc}	1.38 ± 0.01^{bcd}	1.32 ± 0.01^{de}	1.36 ± 0.02^{de}	17.12 ± 1.17^{de}	16.93 ± 1.18^{de}	6.20 ± 0.16^{bc}	6.50 ± 0.33^{b}
GYP	1.36 ± 0.01^{b}	1.39 ± 0.01^{bc}	1.35 ± 0.02^{bc}	1.37 ± 0.01^{d}	17.20 ± 1.15^{d}	17.00 ± 1.16^{de}	6.10 ± 0.24^{bc}	6.52 ± 0.41^{bc}
GYP+FYM	1.29 ± 0.01^{ef}	1.34 ± 0.01^{e}	1.26 ± 0.01^{f}	1.31 ± 0.01^{f}	16.73 ± 1.27^{ef}	16.47 ± 1.13^{f}	7.91 ± 0.33^{a}	8.20 ± 0.24^{a}
HA	1.36 ± 0.01^{bc}	140 ± 0.01^{b}	1.34 ± 0.01^{bcd}	1.38 ± 0.01^{bcd}	18.30 ± 1.46^{ab}	17.87 ± 1.39^{c}	4.90 ± 0.24^{d}	5.20 ± 0.16^{cd}

PM = Poultry manure; FYM = Farm yard manure; GYP = Gypsum; HA = Humic acid (liq.). Values represent means (n=3) ± standard errors. Different lowercase letters (superscripts) in each column show significant difference according to LSD test at $P \leq 0.05$

Discussion

In this study, improved plant density and yield attributes of peanut were observed on the addition of organic and inorganic amendments. Taufiq *et al*. (2016) found improved growth, plants density and yield of peanut on application of GYP and manures. Kausar *et al.* (2020) reported a significant increase in wheat (*Triticum aestivum* L.) yield by the addition of GYP and green manures. Improved yield and growth traits in maize (*Zea mays* L.) by the addition of PM and HA might be due to the addition of organic matter by these amendments, thus improving the physical, chemical, and biological properties of soil, and increasing nutrients availability within the rhizosphere zone, which consequently enhanced overall growth and yield attributes of peanut (Rizk *et al.* 2012; Zhao *et al.* 2016; Hussain *et al.* 2018). Other possible explanations for the improved yield on applying amendments could be the enhanced soil moisture retention, which is directly linked with nutrients mobility and availability as found in present study with increased moisture percentage and nutrient content found in treatment where GYP and FYM applied in combination (Parihar *et al.* 2019; Mariotte *et al.* 2020).

The improved crude protein and oil contents in mustard (*Brassica juncea* L.) by the application of HA and manure were previously reported by Dubey *et al*. (2019). The improved effect on quality of peanut could be due to the increased nutrients uptake particularly of N, and better translocation of assimilates (Ravikumar *et al.* 2019). Combined application of GYP and FYM proved most effective in improving crude protein and oil contents significantly, and this promoting effect can be attributed to the ability of FYM and especially GYP to add sulfur (S) within the soil and as sulfur have major role in synthesis of protein and oil in oilseed plants (Caires *et al.* 2006; Rocha *et al.* 2017; Raza *et al.* 2018; Ariraman and Kalaichelvi 2020; Chahal *et al.* 2020).

The integrated use of different organic and inorganic amendments could significantly improve soil properties (Ahmad *et al.* 2013). In our study, reduced soil bulk density, water infiltration rate and improved moisture contents on application of organic and inorganic amendments were observed. This promotive effect could be due to the fact that organic amendments together with inorganic fertilizers improve organic matter contents, soil aggregation, roots growth and consequently increase the total volume of biopores in the amended plots (Bandyopadhyay *et al.* 2010; Singh and Benbi 2016; Bekele *et al.* 2020) in addition to providing essential nutrients to increase the soil fertility and productivity (Rasoulzadeh and Yaghoubi 2010; Agbede *et al.* 2017). Reduced bulk density on addition of amendments could be due to the increase in overall volume of pore spaces due to organic matter addition (He *et al.* 2020), while the binding/water holding characteristic of the amendments could be the reason of the reduced infiltration rate and increased moisture content (Hudson 1994; Verheijen *et al.* 2010; Aytenew and Bore 2020).

Conclusion

All the tested organic and inorganic amendments in our field trial showed improved effects on yield, quality of peanut and soil physical properties. While, co-application of GYP and FYM was found to the most effective in improving yield attributes (100 grain weight, no. of pods per plant and pods yield), quality attributes (crude protein and oil content) of peanut, and soil physical properties (bulk density, infiltration rate and moisture percentage). Furthermore, our findings suggest that co-application of GYP and FYM under rain-fed conditions could serve as a better alternate to the excessive usage of single source chemical fertilizers in order to achieve the ultimate goals of sustainable food production having improved yield, quality and soil physical health.

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Author Contributions

RL and ME conceptualized the study, conducted the experiment, managed the resources and analyzed the data, MJA, MIK and MSK conducted the statistical analysis, MJA, MIK and MSK wrote original draft of the manuscript, RL supervised the study and all processes. MAB visualized the experiment conceptually, SH contributed in editing the manuscript. MIK corresponded to the journal for submission and review. All authors have read and agreed to the submitted version of the manuscript.

Conflict of Interest

Authors declare no conflict of interest.

Data Availability

We hereby declare that data related to this article, are available with the corresponding author and will be produced on demand.

Ethics Approval

Ethical approval is not applicable in this study.

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