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MANURE ADDITIONS IN DIFFERENT TEXTURE SOILS TO ENHANCE MAIZE ROOT PENETRATION

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ABSTRACT

The properties of the soil, both physical and chemical, have a considerable impact on the development and production of the crops. The soil texture, an unchanging soil physical property that affects the soil, has a secondary effect on crop growth. The goal of this study is to determine how different textures and organic amendments affect the root development of maize, which in turn affects the plant's ability to grow. In 2019 a pot experiment was conducted at Arid Zone Research Center in DI Khan, Pakistan, using two native soil types, clay loam and sandy loam. Farm manure was added as an amendment to the trial at rates of 0 (T_0), 5 (T_1), 10 (T_2), and 15 (T_3) Mg ha^{-1}. Half the recommended NPK dose of 150:90:60 kg ha^{-1} was added to each treatment pot. The plant parameters including shoot length (89.6 cm), fresh weight (176.42 g), and dry weight (16.89 g), as well as root length (39.1 cm), fresh weight (37.11 g), dry weight (11.01 g) and 100-grain weight (22.23 g). The organic amendment added at a rate of 10 Mg ha^{-1} (T_2) under sandy loam texture produced noticeably higher values. It was concluded that every plant parameter increased as the quantity of organic matter increased in the soil, however as the quantity of added organic matter reached 10 Mg ha^{-1}, a significant drop was noticed. Additionally, it was discovered that crops performed well in sandy loam than in clay loam soil.

***Keywords**: Soil, Texture, Organic manure, Root extension, Grain yield*

INTRODUCTION

The third most important cereal staple after wheat and rice is maize (*Zea mays* L.) which is a major source of revenue for farmers (Tiwari and Yadav, 2019). Maize is cultivated on almost 1.11 million hectares of land, with an average of 3600 kg per hectare yield, yielding cumulatively 4.04 million tons of produce annually. More than 90% of produce comes from the two (Punjab and KPK) main provinces, with a wide-ranging contribution to the agricultural economy of the country (Zulfiqar and Thapa, 2017). Since it matures in such a short amount of time, maize is grown twice a year, in the spring and the fall. The starch content of maize is 80%, while the fiber content is 3.5%, the sugar content is 3%, the protein content is 10%, and the oil content is 4.5% (Ai and Jane, 2016). The relative proportion of three soil particles (sand, silt, and clay) is the texture of the soil. The texture is an invariable soil physical characteristic that has a significant influence on soil fertility, water holding, infiltration and conduction, aeration, and soil porosity (Usharani *et al*., 2019). Texture also has an indirect impact on root length proliferation and plant growth. When soil becomes compacted, root penetration and proliferation are both stifled, which in turn slows the growth of maize (Strock *et al*., 2022). The nature of the soil and its properties are the primary elements that control the rooting patterns of the plants. The diameter and pattern of lateral root branching, as well as the growth of root hairs, are both influenced by the texture of the soil (Jorda *et al*., 2022). When opposed to sandy soil, soils with a finer texture offer more resistance to the infiltration of plant roots (Strock *et al*., 2022).

Because of the surface crusting in fine-textured soils, there is a reduction in germination and seedling emergence, which ultimately leads to a low crop stand (Kim and Park, 2010). Because of its poor retention capacity and increased leaching losses, sandy soil has a lower nutrient content than clayey soil, which results in higher levels of major soil nutrients i.e., nitrogen, phosphorus, and potassium in the soil. Nutrient availability is also reliant on the texture of the soil (Xia *et al*., 2020). Biological residues that have accumulated over soil are a fundamental source of nutrients and are referred to collectively as soil organic matter (SOM). SOM has a significant effect on the soil's physical and chemical characteristics, which in turn has an indirect effect on root proliferation (Lal, 2020). The use of organic manure helps to prevent water loss by evaporation, the removal of the soil surface, and the seeping of nutrients out of the rhizosphere (Shahzad *et al*., 2020). The use of organic manure helps preserve soil fertility since it improves the soil's physical health and, due to its gradual mineralization process, provides nutrients at the optimal moment when they are needed (Shahzad *et al*., 2021). Because they contain less than 1% organic matter, the soils of Pakistan are considered to be poor in organic matter (Fatima *et al*., 2021). Organic farming is the recommended method of restoring nutrient-depleted and physically deteriorated soils throughout the entire planet (He *et al*., 2021). Not only does the presence of organic matter raise the level of carbon and nitrogen in the soil, but it also makes it easier for plants to absorb nutrients (de Souza Almeida *et al*., 2021). Compost treatment, as opposed to mineral fertilizer, resulted in much more root growth, according to Xin *et al*. (2016). The usage of organic manure results in an improvement in the physicochemical and biological health of the soil, which advances an expansion in crop output and quality (Meddich *et al*., 2020). The supplementation of organic matter lessens the soil's tendency to become compacted and increases the capacity of the soil to retain water, both of which lead to increased crop growth and development (Prasad *et al*., 2017). The decay of organic substances results in the flocculation of soil particles, which improves soil structure and water conduction, increased porosity, and a reduction in compaction (Lasareva *et al*., 2019). There is no viable alternative to the usage of chemical fertilizers because organic manures are unable to satisfy the crop's nutritional demand over a vast area due to infinite requirements, a slower release of nutrients, and a high level of labor requirement (Wu and Ma, 2015). The usage of organic manure and mineral fertilizer together is advantageous in terms of boosting crop output as well as the health of the soil (El Sheikha, 2016). In an intense cropping system, the use of organic and synthetic fertilizers helps to maintain crop output while also conserving the soil's capacity for nutrient uptake (Egodawatta *et al*., 2012). In the long run, the application of combined and suiTable amounts of organic and inorganic manures not only satisfies the nutrient requirements of crops but also repairs and maintains the health of the soil and the productivity of the land (Jaja *et al*., 2017). It was hypothesized that the soils of heavy textures amended with organics allow more root penetration of plants. Considering the facts presented above, the current study was conceived to determine the effect that organic matter has on root proliferation and maize growth in soils of varying textures.

MATERIALS AND METHODS

At the research area of the Arid Zone Research Center in DI Khan, a field experiment was carried out during kharif season of 2021 to determine the impact that various textures and manure rates have on the growth and root proliferation of maize. Maize hybrid Shahenshah was used as test crop. During this research, two distinct types of soil, namely sandy loam and clay loam, were utilized. This soil was collected from the surface layer (0-15 cm) of the Center's research field and the riverine belt of DI Khan. It was then air dried, ground, thoroughly mixed, and put through a 2 mm sieve before being analyzed for various pre-sowing soil characteristics using the analytical methods described by the US Salinity Lab (Staff, 1954). The hydrometer method was used to conduct the particle size analysis of these samples (Gee and Bauder, 1986). The soil textural class was established by following the International textural triangle (Moodie *et al*., 1959), and the initial findings are provided in Tables (1 and 2).

Table-1: Particle-size analysis of soils

Determination	Unit	Value	
		S_1	S_2
Sand	%	53.2	36.8
Silt	%	25.7	23.2
Clay	%	21.1	40
Textural class	-	Sandy loam	Clay loam

Table-2. Physical and chemical characteristics of soil used for the study

		Sandy Loam	Clay Loam
Parameter	**Unit**	**Amount**	**Amount**
Bulk density	g cm^{-3}	1.46	1.53
EC_e	mS cm^{-1}	1.47	1.49
pH		8.0	8.3
Saturation percentage	%	28.9	37.1
Na^+	me L^{-1}	4.38	1.67
$Ca^{2+} + Mg^{2+}$	me L^{-1}	13.11	10.09
CO_3^{2-}	me L^{-1}	0.52	0.67
HCO_3^-	me L^{-1}	9.1	10.3
Cl^-	me L^{-1}	3.78	5.41
SO_4^{2-}	me L^{-1}	0.59	0.67
Organic carbon	%	0.38	0.64
NO_3^{-1} nitrogen	mg kg^{-1}	3.7	4.9
Available phosphorus	mg kg^{-1}	8.45	8.97
Available potassium	mg kg^{-1}	110.7	121.8
Organic matter	%	.34	.56

Each pot with a polythene lining received 10 kg of soil, which was then treated with 0 (T_0), 5 (T_1), 10 (T_2), and 15 (T_3) Mg ha^{-1} of farm manure. Each treatment combination was thrice replicated, and the experiment was arranged in a completely randomized design with factorial arrangement. Mineral fertilizer was applied at a rate of 75 kg N, 45 kg P, and 30 kg K per hectare. The total dosage of phosphorus and potassium was added at the start, but the nitrogen application was split up into three times. In each container, eight seeds were planted, and once they germinated, the number was reduced to five. The watering of the plants and the application of any necessary pesticides and fertilizers were done as needed. The crop was harvested when it had reached its full maturity, and after recording plant yield and growth characteristics, a test called the least significant difference (LSD) test was used to evaluate the difference in treatment means (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

The highly significant and unchanging aspect of soil known as soil texture influences both the physiochemical makeup of the soil and the vegetative properties of plants. The addition of manure not only increases the soil's organic content and nutrient-holding capacity but also indirectly enhances plant development by enhancing soil structure. Following a completely randomized design with a factorial arrangement, the current pot study was carried out to assess the contribution of various texture soils treated with various amounts of farm manure in a difference in maize growth and root proliferation at the research area of AZRC DI Khan. The discussion of the findings is as follows.

Shoot length (cm): The shoot length of the plant often indicates plant growth. (Table-3) presents data that demonstrates a considerable upsurge in plant shoot length with escalating manure rate. The data reveal the effect of different textured soils with diverse manure addition rates on shoot length. The treatment that applied 10 Mg ha^{-1} of farm manure had the longest shoots, followed by treatments that applied 5 Mg ha^{-1} and 15 Mg ha^{-1}, whereas the control treatment that did not apply any manure had the shortest shoots. According to data on soil texture, sandy loam soil produced noticeably longer shoots than clay loam. It was also noted that the interaction between texture and manure had statistically significant effects. According to Doung *et al*. (2012), raising the amount of manure on various textured soils caused a considerable rise in plant lengths. The manure application releases nutrients upon decomposition therefore behave as slow-release fertilizers and boosts the plant growth. Yilmaz and Sonmez (2017) who observed increased plant heights with manure application compared to control treatment lend confirmation to our findings. The manure application increases water retention, there is more water available for evapotranspiration, which causes crop plants to grow taller (Blanco-Canqui *et al*., 2015). Compared to sandy loam and sandy clay loam soils, fine-textured soils limit plant growth and development because they have more root penetration resistance and less aeration (Gathala *et al*., 2012).

Shoot fresh weight (g): Maize is also utilized as cattle feed. Increased shoot weight translates into higher fodder yield. To meet the needs of the cattle, an amendment to boost fodder yield is applied, and as a result of the herd's increased size, photosynthesis increased. It elaborates on the significant effects of various farm manure amounts and soil texture classifications (Table-3). Information about levels of farm manure Maximum fresh weight of the shoot was exhibited at 10 Mg ha^{-1}, and it was followed by treatments that received farm manure application at 5 Mg ha^{-1} and 15 Mg ha^{-1}, with the control treatment receiving the lowest value. Sandy loam soil yielded more shoot weight than clay loam texture, taking soil texture into account. More growth due to manure application results into more fresh biomass of plants. A significant interaction between different textural classes and manure rates was also noted. Glab *et al*. (2010) and Lentz *et al*. (2019) discovered that applying varied amounts of farm manure to various soil textural classes causes a considerable difference in the fresh weights of plants.

Shoot dry weight (g): On a minimal scale, maize shoot is sliced and fed to animals. In Pakistani areas, maize shoot is primarily utilized as fireplace fuel to prevent the need to cut down trees. Results provided show that raising agricultural manure levels and various textural classes have a significant influence (Table-3). Data show that treatments fertilized with 10 Mg ha^{-1} farm manure, followed by 5 and 15 Mg ha^{-1}, respectively, have maximum shoot dry weights that are considerably greater than controls. Sandstone loam performed better than clay loam when texture was taken into consideration. A significant interaction between different farm manure amounts and distinct soil textures was also noted. Adugna (2016) and El-Kader *et al*. (2010) discovered that increasing farm manure levels on various textured soils had a substantial rising impact on plant weights due to more growth and development when the plants were dried. Doung *et al*. (2012) supported our findings by demonstrating increased shoot growth and weights after manure treatment.

100-Grain weight (g): The grain that is harvested from the crop and consumed by the farmer is the single most significant thing that is required of him. Therefore, the sale of grain is how income is obtained from crops. In addition to the yield indices, the 100-grain weight has the preeminent position. The influence of a variety of textural classes combined with a range of manure application rates has a considerable effect on the crop's 100-grain weight, as shown in (Table-3). The weight of 100 grains was found to be at its highest in the pot in which 10 Mg ha^{-1} of agricultural manure had been put, followed by 5 Mg ha^{-1}, 15 Mg ha^{-1}, and 0 Mg ha^{-1}, where it was at its lowest. The results show that the crop's production efficiency was greatly affected by the textural class of the soil, and it is clear from those findings that sandy loam delivered appreciably elevated yields than clay loam did. When the interaction of farm manure and the textural class was considered, the results showed that increasing the amount of farm manure resulted in a considerable improvement in the grain yield of the crop. Farhangi-Abriz *et al*. (2021) found that the rate of application of farm manure increased on soils of varying textures resulting in a greater increase in the weight of 1000 grains. The increase in this parameter is due to the improved mineral nutrition provided by the decomposition of manure. Ahmad *et al*. (2020) found that treatments that included the application of organic manure resulted in 13.86% greater 1000-grain weight than the control

Table-3 Manure application and textures impact on Shoot parameters and 100-grain weight of maize

Manure	Texture	Length (cm)		Fresh Weight (g)		Dry Weight (g)		100 Grain weight (g)	
		S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
T_0		51.7 f	47.6 g	102.31 f	97.12 g	8.99 cd	6.93 e	17 f	16.3 g
T_1		84.1 b	69.9 d	151.23 b	133.26 d	13.98 b	10.0 cd	20.5 b	18.77 d
T_2		89.6 a	70.7 d	176.42 a	139.41 d	16.89 a	11.01 c	22.23 a	20.3 b
T_3		80.3 c	59.6 e	142.50 c	113.08 e	14.07 b	7.98 de	19.3 c	18.0 e

Root length (cm): The root is the most important organ of the plant for taking up nutrients. The longer the root, the greater its capacity for absorbing nutrients, which in turn will stimulate further plant development. Therefore, increased plant growth can be attributed to the variables that promote increased root growth. Table-4 displays root penetration data, which suggests that pots in which 10 Mg ha^{-1} of farm manure was added established roots to expand more than 5 and 15 Mg ha^{-1}, which are likewise much extended than control roots. These results are compared to the data shown in Table-4. When compared to clay loam, sandy loam soils offered less resistance to the penetration of root systems, which resulted in longer root systems. According to Chen and Weil (2011), root penetration of crops is a consequence of both the soil texture and the subsoil compaction. Shahzad *et al*. (2014) compared fine-textured soil, which inhibited root penetration, coarse textured (sandy soil) was found to have a greater amount of root penetration than fine-textured soil. Root extension is significantly impacted by a rise in inorganic ions and the release of humic ingredients caused by the decay of organic manures that have been applied (Xiang *et al*., 2017).

Root fresh weight (g): Higher weights should be anticipated based on the root's length. The size of the roots can also be used to gauge the plant's overall growth. This is because a plant will be in better shape if its roots can provide it with the right nutrition, which will result in improved health. The root's close association with the soil solution enables this. The information in Table-4 shows the variety of root weights that can be obtained by using different modifications. When farm waste is considered, the pot that received 10 Mg ha^{-1} produced higher root weight than the pots that received 5, 15, or 0 Mg ha^{-1} of treatment. Clay loam resulted in heavier soil, even though the texture of sandy loam permits higher root penetration. The diverse farmyard manure applications and the soil texture were also demonstrated to have significant interactions that affected the fresh weights of the roots. According to Canellas and Olivares (2014), the degradation of manures results in increased root proliferation, lateral root extension, and root hair formation, which results in higher weights of roots under various soil textural classes. Lynch *et al*. (2012) presented increased root growth because of the addition of organic matter, which serves as a buffer in the soil and creates a favorable environment for the establishment of roots, which is consistent with our findings.

Root dry weight (g): The information in Table 4 shows the variation in root weights. The pot that received 10 Mg ha^{-1} farm manure produced higher root weight than the pots that received 5, 15, or 0 Mg ha^{-1} of treatment. Although sandy loam has a lighter texture than clay loam, it allows for more root penetration, which results in heavier loads. The diverse farmyard manure applications and the soil texture were also demonstrated to have significant interactions that affected the dry weights of the roots. According to Calvo *et al*. (2014), the decomposition of organic materials increases root proliferation, lateral root extension, and root hair formation, which yields more weights of roots under various soil textural classes. Montiel-Rozas *et al*. (2016) presented increased root growth because of the addition of organic matter, which serves as a buffer in the soil and creates a favorable environment for the establishment of roots, which is consistent with our findings.

Table-4 Effect of soil texture and different manure rates on root parameters

Manure	Texture	Length (cm)		Fresh Weight (g)		Dry weight (g)	
		S_1	S_2	S_1	S_2	S_1	S_2
T_0		21.2 f	21.3 f	19.96 f	19.76 f	3.97 e	3.78 e
T_1		33.7 b	27.2 d	31.89 b	26.87 d	7.25 b	5.17 d
T_2		39.1 a	32.8 c	37.11 a	29.45 c	11.01 a	5.99 c
T_3		32.3 bc	24.4 e	29.14 c	23.97 e	6.99 bc	5.01 d

CONCLUSIONS AND RECOMMENDATIONS

The development and yield parameters of the maize crop were considerably improved by increasing the rate of manure application in light as well as heavy texture soils. The sandy loam texture is superior in terms of increasing growth metrics, and the application of 10 Mg ha^{-1} of farm manure yielded the highest possible output. Therefore, it is strongly recommended to incorporate organic materials not only to improve soil health but also to sustain yield.

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AUTHOR CONTRIBUTIONS

Ayesha Malik and Sami Ullah conducted this research trial. Qurat Ul Ain Fatima, Tayyba Umer, Asghar Ali Khan, and Beenish Butt wrote this paper. Ghazanfar Ullah and Ayesha Irum analyze the data. Umar Khitab Saddozai set the references. All authors read and approved the final version.

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