Research Article

Effects of Sand and Clay Compositions on Growth and Biochemical Aspects of *Hordeum vulgare* (L.) and Soil Physico-Chemical Properties

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Abstract | Crop productivity mainly depends on soil type, soil composition and texture particularly, the ratio of sand and clay. The current research was carried out to investigate the effect of different ratios of sand and clay composition on growth and biochemical aspects of Barley (*Hordeum vulgare* L.) and variations in soil physical and chemical properties were tested. During the experiment, plants were grown in eleven sets of soil combinations texture wise with varying ratio of sand and clay along their chemical properties. Different growth parameters based on physiological functioning and biochemical aspects were observed for various physical and chemical properties of soil provided to plants for growth optimization.. Barley flourished only well in sandy soil. The number of leaves, branches, fruits, plant height, proteins, and chlorophylls were significantly ($P<0.05$) increased in sandy soil proportion whereas in soil analysis moisture, hygroscopic water, pH, cation exchange capacity (CEC), chlorides, organic matter were significantly ($P<0.05$) increased for the soily soil in same proportion that is of sandy soil. This reveals that Barley should be grown in sandy soil for its better growth and productivity. The least growth parameters were noted on soil with more clay retaining most of moisture and inhibiting growth due to soil pH.

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Introduction

Soil is the fundamental unit and supportive medium for plant roots anchorage, proliferation and source of moisture and nutrients. Soil texture and composition are vital for plant growth. Environmental changes and management practices can modify soiltexture and chemical propeerties. Effective soil management can enhance crop productivity by maintaining good soil texture, oxygen taking quality, water holding capacity and balanced pH. Soil degradation is generally associated with multiple factors i.e., soil erosion, nutrient leeching, and imbalance combinations of various soil particles and proportions. All these contribute to soil imbalance pH associated with water mineral absorption and affecting growth and productivity of the crops (Chai *et al*., 2016). Similarly, the plants are also affected by the saline stress specially sodium chloride (Yousaf, 2022) produce imbalance in the pH.

The pores of soil inside the rhizosphere hold dampness that adheres to soil particles by surface pressure or may top off the pores in part or completely soaking with it and help to the supplements to dissolve the minerals in the water, essentially required for plant growth and development. The roots of most plants additionally require oxygen for respiration. Thus, porosity plays a key role in soil aeration and root respiration. Carminati *et al*. (2010) revealed the influence of mucilage on the water holding capacity of the soil immediately around the root, and its implications for hydraulic continuity around the root system was demonstrated by (Moradi *et al*., 2011). In compacted soils, the influence of plant-derived exudates has been highlighted to improve mechanical conditions for root penetration (Oleghe *et al*., 2017). A part of the soil is an aggregate of solid material, comprised of minerals and organic matter, and open spaces, called pores. By volume, most soils are approximately 50 percent solids and with 50 percentporocity . The mineral matter composes about 45 to 47 % of the total soil volume (Tóth *et al*., 2016).

The major components of soil are sand, silt, and clay, this distinction is built on particle size and their chemistry (Taiz and Zeiger, 2006). Clay is crystalline with a repeating unit of planes of oxygen with silicon and aluminum atoms holding oxygen atoms together by ionic bonds (Uddin, 2017). The USDA system has devised twelve major classes relative to different ratios of sand, silt, and clay with loam having equal ratios of all three components (Willaredt and Nehls, 2020). In Pakistan Western highlands have bare rocks without any soil cover, while in Indus plains the higher areas are the subject with sands and the lower basins with loam and intermediate might have silt and loam (Khan, 2000). The topographic variations affect the cultivation practices, therefore, it is necessary to optimize the soil management practices to enhance crop productivity cost-effectively.

Barley (*Hordeum vulgare* L.) belongs to the genus Hordeum in the tribe *Triticeae* of the grass family, *Poaceae*. The *Triticeae* tribe is a temperate plant group containing several economically important bowls of cereal and forages (Riehl, 2019). The stems are erect and made up of hollow, cylindrical internodes, separated by the nodes, which bear the leaves (Cakmak, 2008). The ligule and auricles distinguish *Hordeum vulgare* from other cereals as they are smooth, enveloped the stem, and can be pigmented with anthocyanins. Barley Plants contains varying amounts of tocopherols and tocotrienols (49.9-67.6mg/kg) and vitamin E content (vitamin E equivalent; 15.7-20.1mg/kg) (Granda *et al*., 2018). The beta-glucan component of *Hordeum vulgare* is believed to slow gastric emptying time, prolong the feeling of fullness, and stabilize blood sugars. The cultivation of Barley in different geographic planes and soil structures is greatly affected by soil structure and compositions. As it has been studied from the literature that favorable soil structure, particularly sand and clay ratio and aggregate stability are major contributing factors for soil fertility, porosity, decreased erodibility, and higher crop productivity. Therefore, a study was carried out to evaluate the suitable soil composition, in terms of sand and clay ratio for the growth, biochemical aspects, and cultivation of Barley.

Materials and Methods

Growth experiment

This experiment was designed to evaluate the effect of different ratios of two types of soil present in District Mardan. The composition of two selected types of soil was: Type 1 (Sandy Soil) Contain, 77.4% Sand, 10.1% Silt, and 12.5% Clay component in it. Type 2 (Clay Soil) contain, 17.7% Sand, 14.1% Silt and 68.2% Clay component in it. The experiment was comprised of 44 pots which were divided into 11 sets each set had different ratio of sand and clay, such as i) 0% sand +100% Clay, ii) 10% sand +90% Clay, iii) 20% sand +80% Clay, iv) 30% sand +70% Clay, v) 40% sand +60% Clay, vi) 50% sand +50% Clay, vii) 60% sand +40%Clay, viii) 70% sand +30% Clay, ix) 80% sand +20% Clay, x) 90% sand +10% Clay, xi) 100% sand +0% Clay. Each pot was saturated with water and a seedling with three leaves stage was transplanted in each pot. The size of the pot was 10 cm in height and 13 cm in diameter from the top and 10 cm in diameter from the base. Plants were grown for four months in the netted greenhouse with temperature ranging from 8 °C to 22 °C with 65-70% humidity. During whole duration, the plants received six times rainfall on average 5.4 mm rainfall per hour. The plants were daily watered in the morning time in amount of 40-45 mL. The plants were growth in the month of November, 2020 and harvested in the month of Feburary, 2021 and short after the harvest, the measurements were taken. Plants were harvested and their growth parameters in terms of plant height, fresh and dry biomass were measured. The root length was measured in the average centimeters of twelve plants of the same treatment condition using scale. Similarly, the number of fruits/ plant, leaves/plant and branches/plants was determined by taking twelve plants of the same treatment condition and taken in average. The biochemical attributes were calculated by standard methods: chlorophyll and carotenoids (Maclachlan and Zalik, 1963), reducing sugar (Nelson, 1944), total carbohydrates (Fales, 1951), phenols (Malick and Singh, 1980), total soluble proteins electrolyte leakage (Lutts *et al*., 2004), relative water content (Garcia-Mata and Lamattina, 2001) and leaf water loss (Clarke and McCaig, 1982).

Soil analysis

Soil analysis was made according to the standard methods, soil moisture by the method of (Smith, 2000), water movement in soil by the method of (Amoozegar, 1986), Gravitational water loss was measured using gravimetric method with oven drying. The moist soil was taken weighted and then dried in oven at 100°C for 48 h and then reweighed. The hygroscopic water content was measured by taking 10 % soil from the pot, weighted it and then provided 60 to 80 % relative humidity in the plant growth chamber at 25 °C for 24 hours and measured the weight. The capillary water rise was measured using the formula 2T/rpg wherein T is the surface tension of the water raised in the column, r is the radius of the column, p is the density of the water and g is the moment of water in the column measured in per second. The pH test by the method of (McLean, 1983), electrical conductivity by the method of (Rhoades, 1983),

Table 1: *Effects of different ratios of sand and clay in soil on soil moisture, hygroscopic water, gravitational water loss, capillary water, and water movement in the soil.*

Treatment	Gravitational Water Loss (ml)	Hygroscopic water (ml)	Capillary water (ml)	Moisture %	Water Movement in Soil (cm/min)
100% Sand	85.593e	0.260a	14.146a	16.220bcd	18.366d
	±0.611	±0.075	±0.654	±0.436	±1.625
90%Sand+10%Clay	84.023de	0.493a	15.483ab	5.093a	11.366bc
	±0.074	±0.102	±0.177	±2.634	±0.883
80%Sand+20%Clay	83.183cde	0.406a	16.410ab	10.756abc	10.200b
	±0.296	±0.108	±0.259	±2.183	±1.474
70%Sand+30%Clay	82.630cde	0.603a	16.770abc	9.880ab	13.866c
	±0.706	±0.151	±0.747	±1.092	±0.696
60%Sand+40%Clay	82.630cde	0.553a	16.816abc	18.430cde	11.700bc
	±0.765	±0.123	±0.69	±3.956	±0.300
50% Sand+50%Clay	76.753ab	2.013b	21.233c	17.073bcd	6.966a
	±0.915	±0.282	±0.932	±1.313	±1.297
40% Sand+60%Clay	82.953cde	1.830b	15.216a	16.650bcd	7.166a
	±1.854	±0.399	±1.639	±2.222	±0.284
30% Sand+70%Clay	79.606abcd	3.290c	16.903abc	20.180de	5.200a
	±2.347	±0.32	±2.613	±3.117	±0.36
20% Sand+80%Clay	80.846bcd	1.366ab	17.786abc	25.196e	5.566a
	±0.441	±0.15	±0.541	±2.747	±0.176
10% Sand+90%Clay	78.66abc	3.356c	17.983abc	22.026de	4.700a
	±0.754	±0.777	±0.347	±1.569	±0.435
100% Clay	75.586a	4.453d	19.96bc	17.053bcd	4.400a
	±2.944	±0.547	±2.772	±2.837	±0.757
$LSD_{0.05}$	0.052	0.058	0.051	0.056	0.065
Probability Level	P<0.01	P<0.001	P<0.05	P<0.001	P<0.001

Means followed by different letters in the same column differ significantly at the 95% probability level according to New Duncan's Multiple Range Test.

Chloride, bicarbonates, soil gypsum by the method of (Richards, 1954) soil organic matter by the method of (Nelson, 1944). The experiment was set up in a completely randomized design (CRD) with three replicates. Collected data were analyzed statistically by using SPSS 14 to an analysis of variance (ANOVA) and the means compared by Duncan's multiple range test ($P < 0.05$).

Results and Discussion

Physical Properties of Soil

Results presented in Table 1 showed some physical properties of different proportions of clay and sandy soil. The soil at a concentration of 20% sand showed a significant ($P<0.001$) increase in soil moisture. However, the soil moisture was increased further when the ratio of clay increased. The sole reason is that clay bears a net negative charge and thus shows electrostatic attraction for water molecules (Delville, 1993). In some other studies, water retention is affected by the texture of soil (Razzaghi *et al*., 2020) as some clay minerals like Montmorillonite, iron oxide, vermiculite, and quartz increases the moisture-retaining abilities of clays which further affect the special distribution of forest and grasslands (Riddle and Bateman, 2020). Water held in pore spaces is called hygroscopic water (Martin and Gonzales, 2017). More pores spaces occur in clay soils. The highest values of hygroscopic water were measured in 100% clay which is also statistically significant ($P<0.001$). The gravitational water loss is more prominent in 100% sand which is significant ($P<0.01$) as well with a general increase in sand proportion the gravitational water loss is prominent this is in agreement with work done by (Pardo *et al*., 2019). Soil with 50% sand exhibited significant ($P<0.05$) in capillary water as the pore space determines water movement in soil (Gharedaghloo *et al*., 2020). Clay has higher total pore space, but smaller-sized pores than sand (Pardo *et al*., 2019). The highest capillary water was recorded for soils when both clay and sand were coupled in equal proportion. Soil with 100% sand showed a significant ($P<0.001$) increase in water movement in the soil these values showed a decline when soils are added with clay and the least values were observed with 100% clays as they have negative charge smallest size of 0.002mm, while the size for sand is 0.05mm This smaller size of clay increases aggregate surface area and the negative charge holds attraction towards the water and both these factors decline water movement. (Pardo *et al*., 2019).

Chemical Properties of Soil

Results in Table 2 showed some chemical properties of different proportions of clay and sandy soil. There is approximately a linear increase in pH values for the increase in clay contents in the soil while significantly ($P<0.001$) higher values were observed for soils with 100% clay which agrees with the results of other researchers (Evenson *et al*., 1998). With the increase in clay contents, the cation exchange capacity of soil also increases, the significant ($P<0.001$) highest values were observed in 100% clays which agree with (Arthur *et al*., 2020). Lower values of chlorides were seen from soils with high ratios of sand. These results agree with (Domeignoz-Horta *et al*., 2020). In some studies, soil chloride profile is used to estimate moisture (Huang *et al*., 2017) this water might be present physically but physiologically absent as chloride lowers soil water potential (Wang *et al*., 2020). The soil sample each with a different percentage of sand and clay was checked for bicarbonate ions, the soil with 70% sand exhibited a significant ($P<0.001$) increase in its values. Three soil samples (from 100% sand to 70% sand) exhibited relatively increased values for bicarbonate ions than all other samples. Also, all samples were analyzed for carbonates but all readings were recorded negative. The soil with 40% sand exhibited significant ($P<0.001$) highest values of gypsum, with the addition of clay the values of gypsum increase which agree with (Latifi *et al*., 2018). Soil containing 20% of sand exhibited a significant increase ($P<0.001$) values of soil organic matter and percentage organic carbon. In general terms, more enhanced values were found in soils with comparatively high ratios of clay to sand. These results are in line with (Follett *et al*., 2020; Babaoglu and Simms, 2020). Organic matter stays for a longer time in clayey soils (Koegel-Knabner and Rumpel, 2018).

Growth Attributes

Figures 1 and 2 showed different growth parameters of the *Hordeum vulgare* plant grown in different proportions of clay and sandy soil. The plants that were grown in soil with 100% sand exhibited a significant ($P<0.001$) increase in plant height, and with the increase in clay content in the soil, decreased plant height was observed. Plants that were grown in soil with 40% sand showed a significantly ($P<0.001$) increase in root length, it is more enhanced in sandy soils and those soils with 50-70% clays, on the other side more clays inhibits root growth due to compaction (Abbas *et al*., 2018), reduced infiltration and accumulation of toxic

Table 2: *Effects of different ratios of sand and clay in soil on pH, cation exchange capacity (CEC), soil chlorides, bicarbonates, gypsum, percentage of organic matter, and percentage of organic carbon.*

Treatment	CEC	pH	Bicarbonates	Chlorides	Gypsum	Organic matter	Organic Carbon
	dS/cm		meq/l	meq/l	meq/l	(%)	(%)
100% Sand	0.966a	8.630ab	6.833fg	4.700d	8.889ab	5.673a	3.290a
	±0.033	±0.11	±0.166	±0.399	±0.203	±0.117	±0.068
90%Sand+10%Clay	1.666b	8.660ab	4.933de	1.823bc	7.648a	15.613c	9.056c
	±0.033	±0.034	±0.24	±0.136	±0.183	±0.626	±0.363
80%Sand+20%Clay	2.200c	8.790bcd	5.866ef	1.300ab	10.412bc	14.804c	8.587c
	±0.057	±0.005	±0.371	±0.45	±0.146	±0.443	±0.256
70%Sand+30%Clay	2.266c	8.636ab	7.066g	1.000a	10.887bc	8.427ab	4.888ab
	±0.033	±0.023	±0.176	±0.152	±0.338	±1.16	±0.673
60%Sand+40%Clay	2.733d	8.733bc	3.800abc	1.166ab	13.299cd	12.366bc	7.173bc
	±0.033	±0.012	±0.503	±0.145	±0.626	±2.397	±1.390
50%Sand+50%Clay	3.200e	8.913cde	4.800cd	1.566abc	14.889de	10.584abc	6.139abc
	±0.0031	±0.008	±0.2	±0.176	±0.639	±0.162	±0.094
40%Sand+60%Clay	3.266e	8.493a	3.800abc	1.400ab	51.215g	12.753bc	7.397bc
	±0.066	±0.166	±0.305	±0.152	±2.834	±2.457	±1.425
30%Sand+70%Clay	3.566f	8.953de	3.666ab	1.866bc	15.918e	29.106d	16.883d
	±0.033	±0.02	±0.466	±0.12	±0.599	±3.938	±2.284
20%Sand+80%Clay	3.866g	9.076e	2.733a	1.933bc	46.706h	52.013e	30.170d
	±0.033	±0.012	±0.569	±0.088	±1.097	±1.32	±0.765
10%Sand+90%Clay	4.133h	9.076e	4.133bcd	2.200c	11.202bc	14.886c	8.634c
	±0.033	±0.012	±0.133	±0.173	±1.305	±1.353	±0.784
100% Clay	4.533i	9.300f	3.333ab	1.433ab	20.301f	6.176a	3.582a
	±0.066	±0.011	±0.333	±0.24	±0.684	±0.260	±0.151
$LSD_{0.05}$	0.281	0.065	0.061	0.053	0.104	0.078	0.077
Probability Level	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001	P<0.001

Means followed by different letters in the same column differ significantly at the 95% probability level according to New Duncan's Multiple Range Test.

concentration of carbon dioxide (Mohsin *et al*., 2019). Whereas the soils with high sand contents have high gypsum contents too, in other plants it may reduce root length but not in the case of *Hordeum vulgare* Reduced root length exhibits reduced shoots to clearing the feed-forward theory . A significant (P<0.001) increase in the number of leaves was found for plants grown in soil with 100% sand. The number of leaves per plant bears an inverse relationship with clay contents in soil. Such clayey soils were attributed to high ratios of chloride contents (Table 2) which makes the water unavailable to plants (leading to consequences like low altering carbon dioxide conductance, abnormal leaf anatomy lower photosynthetic rate, programmed stomatal closure and reduced photosynthetic enzyme activity (Jin *et al*., 2020) which results in a reduced number of leaves and their activity. The plants were harvested in soil containing 100% sand exhibited a significant (P<0.001) increase in the number of branches per plant. With increasing clay contents in the soil, the number of branches was declined. This adaptation of *Hordeum vulgare* is dependent on extreme edaphic conditions of soil that select biota for the region with characteristically endemism (Begum, 2017). In our results, the plants that were grown in soil containing 100% sand showed a significant (P<0.001) increase in the number of ears (fruit) per plant, this yield was more enhanced in soils with high ratios of sand only while clay soils had been stressed. *Hordeum vulgare* being susceptible to waterlogged conditions expressed reduced yields when grown in clayey soils. In some studies, it showed about 80% reduction. In our results, the plants that were cultured in soil containing 100% sand showed a significant (P<0.001) increase in fresh and dry biomass. This result meets with the findings of

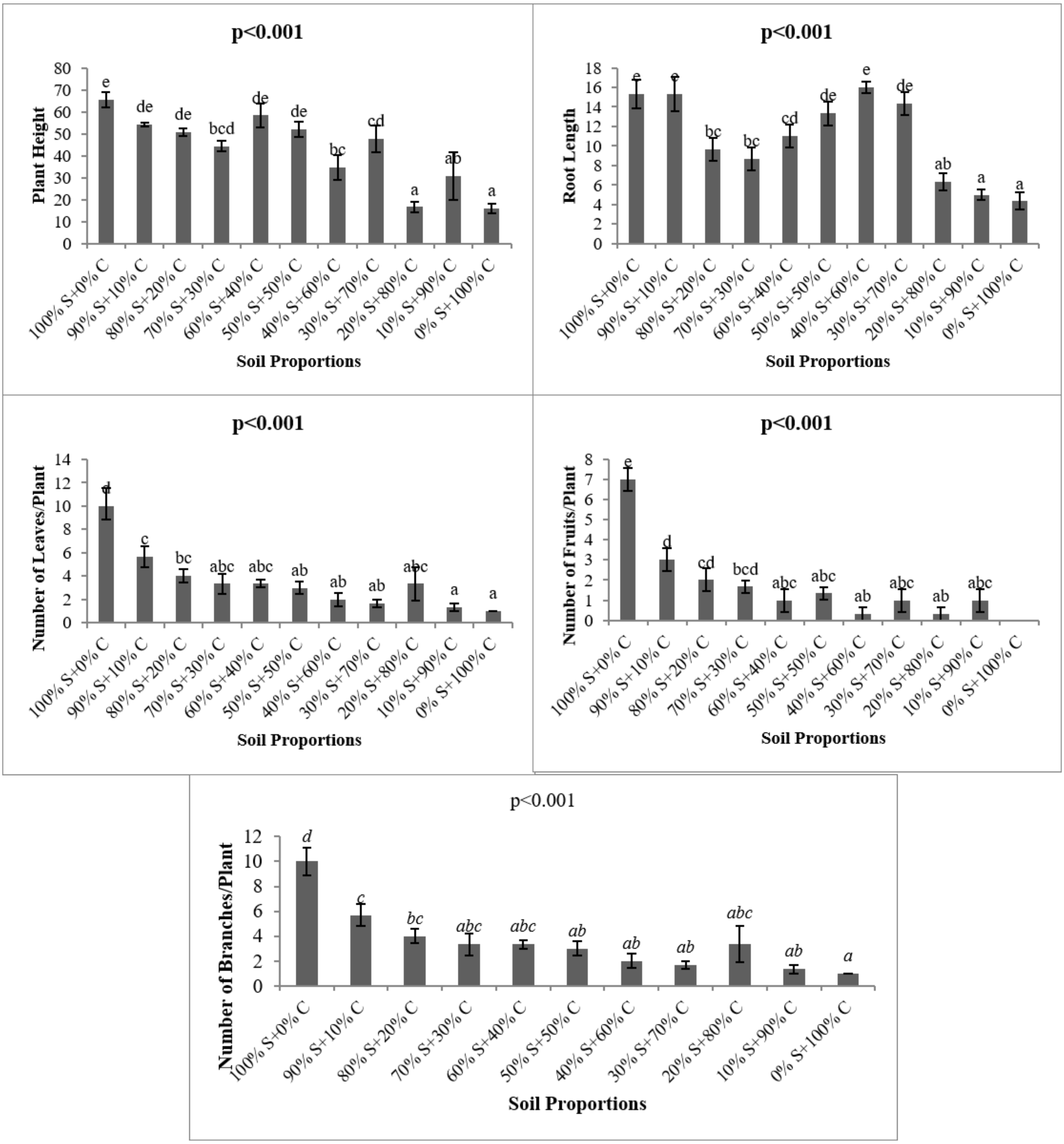

Figure 1: *Effects of different ratios of sand and clay in soil on growth aspects (Plant Height, Root Length, No. of leaves per plant, No of branches per plant, No of fruits per plant) of Hordeum vulgare (L).*

(Mohsin *et al*., 2019) where they got increased fresh and dry biomass for plants grown in sandy soil.

Biochemical Analysis

The plants harvested in soil with 70% sand exhibited a significant ($P<0.05$) increase in total chlorophylls, chlorophyll-a, and chlorophyll-b (Table 3). The soil in which the ratio of sand and clay (7: 3) or any ratio that is in between these reveals higher contents of chlorophylls. These results are in agreement with Jolly and Kumar (2012), while the ratio of chlorophyll a and b was more enhanced in plants harvested in soils with 20% sand (Jolly *et al*., 2012). Carotenoids acts as a defense line against oxidative damage developed by drought stress these conclude that higher contents of carotenoids show plant resistance to these stresses. In our results, those plants that were harvested in soils with 40% sand showed a significant ($P<0.001$)

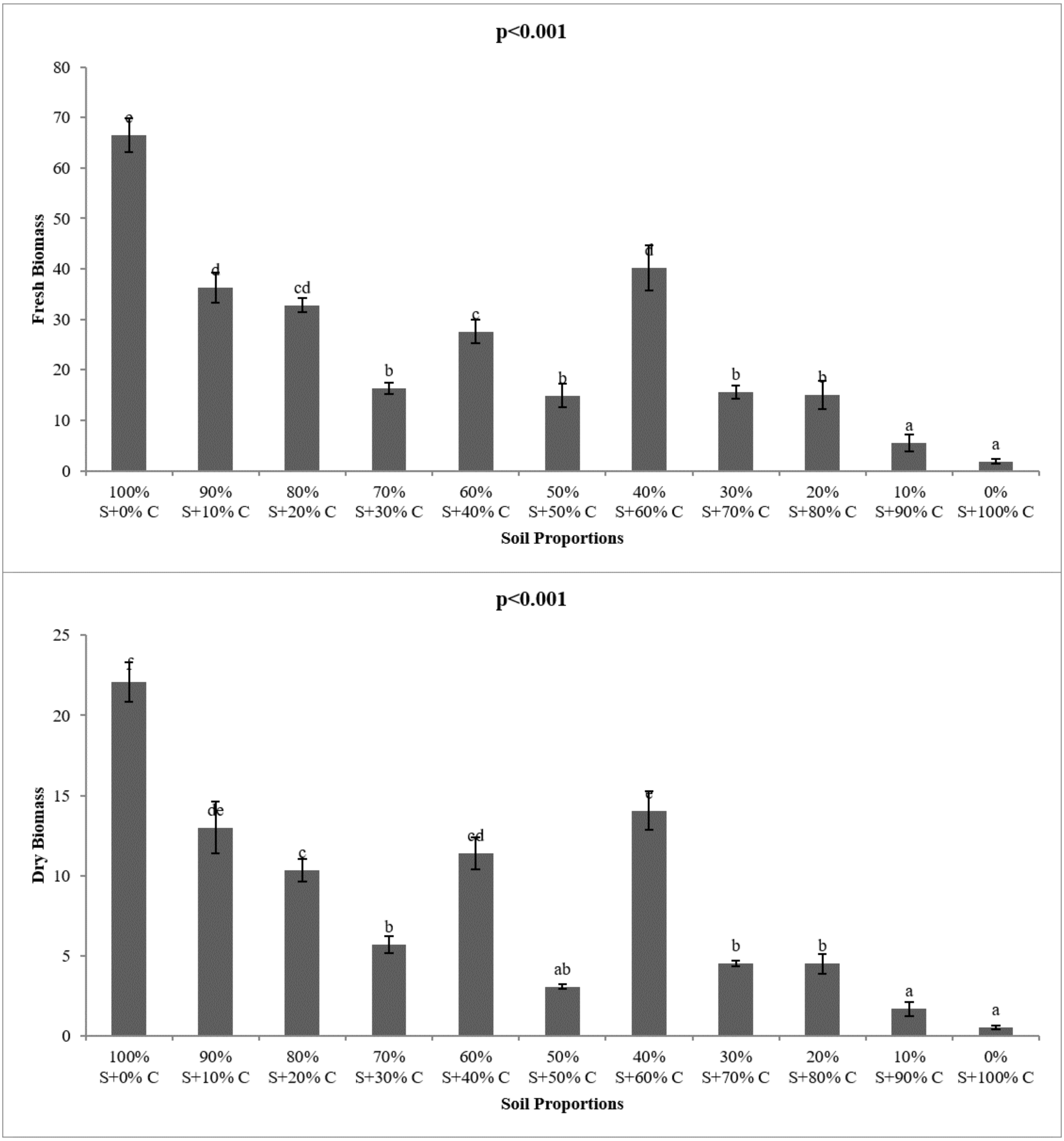

Figure 2: *Effects of different ratios of sand and clay in soil on growth aspects (fresh and dry biomass) of Hordeum vulgare (L).*

increase in the number of carotenoids (Table 3), these plants exhibiting higher contents of carotenoids are met with poor growth and the soils are found with higher gypsum contents lowering the growth in all other plants except *Hordeum vulgare*. It is tolerant to drought stresses or oxidative damages caused by drought stresses as *Hordeum vulgare* bears the ability to develop such higher contents of carotenoids. A test for total soluble proteins was conducted, the significant (P<0.001) highest protein contents were recorded for plants harvested in soil containing 70% sand. In general higher values were recorded for all those plants which were harvested in soil with more than 60% of sand (Table 4). This sorted out that there are some stresses in clayey soils (more than 50% clay) that inhibit the synthesis of globular proteins. The plants were tested for phenolic compounds, significant (P<0.001) increase values were recorded for plants harvested in soils with 60% sand (Table 3). In general terms, the greater values were observed for plants in

Table 3: *Effects of different ratios of sand and clay in soil on Chlorophyll a, Chlorophyll b, total chlorophyll, a/b, proteins, and phenol concentration of Hordeum vulgare.*

Treatment	Chlorophyll-a	Chlorophyll-b	Total Chlorophyll	a/b Ratio	Carotenoids	Total Protein	Total Phenols
	(mg/gm fr.wt)	(mg/gm fr.wt)	(mg/gm fr.wt)		(mg/gm fr.wt)	(mg/gm dry.wt)	(mg/gm dry.wt)
100% Sand	0.739abc	0.178ab	0.918abcd	4.409a	0.337b	0.413d	183.333a
	±0.183	±0.061	±0.243	±0.479	±0.087	±0.014	±60.092
90%Sand+10%Clay	0.468a	0.126ab	0.595ab	4.848a	0.265ab	0.410d	766.666bc
	±0.156	±0.068	±0.219	±1.088	±0.035	±0.023	±296.273
80%Sand+20%Clay	0.448a	0.096a	0.545a	4.688a	0.189a	0.393d	433.333ab
	±0.088	±0.014	±0.099	±0.607	±0.052	±0.006	±88.191
70%Sand+30%Clay	1.015c	0.212b	1.228d	4.804a	0.526cd	0.426d	700.000bc
	±0.044	±0.013	±0.049	±0.346	±0.018	±0.013	±152.752
60%Sand+40%Clay	0.862bc	0.164ab	1.026bcd	5.332a	0.407bcd	0.213b	1033.333c
	±0.047	±0.016	±0.056	±0.504	±0.02	±0.003	±120.185
50% Sand+50%Clay	0.697abc	0.117ab	0.814abcd	5.941a	0.352b	0.193ab	733.333bc
	±0.084	±0.015	±0.099	±0.158	±0.05	±0.006	±185.592
40% Sand+60%Clay	0.969bc	0.177ab	1.146cd	5.474a	0.537d	0.203b	633.333bc
	±0.085	±0.014	±0.099	±0.157	±0.007	±0.023	±33.333
30% Sand+70%Clay	0.675abc	0.095a	0.771abc	7.183a	0.406bcd	0.256c	566.666ab
	±0.106	±0.019	±0.126	±0.371	±0.062	±0.006	±88.191
20% Sand+80%Clay	0.781abc	0.091a	0.873abcd	60.609a	0.383bc	0.220bc	500.000ab
	±0.085	±0.045	±0.123	±54.486	±0.031	±0.01	±57.735
10% Sand+90%Clay	0.749abc	0.173ab	0.922abcd	4.318a	0.373b	0.230bc	533.333ab
	±0.101	±0.006	+0.105	+0.507	±0.044	±0.005	±33.333
100% Clay	0.629ab	0.113ab	0.742abc	5.817a	0.342b	0.156a	433.333ab
	±0.048	±0.02	+0.069	±0.767	±0.0338	±0.006	±88.191
$LSD_{0.05}$	0.058	0.131	0.09	1	0.076	0.054	0.066
Probability Level	P<0.05	P<0.05	P<0.05	NS	P<0.001	P<0.001	P<0.05

Means followed by different letters in the same column differ significantly at the 95% probability level according to New Duncan's Multiple Range Test.

soil with 70% sand to 40% sand. There are reports for the concentration of soil phenols (produced by plants) dependent on plant species and greater in sandy than loamy soils, (Pereira, 2021)this refers that phenol is synthesized by plants depending on soil type. The concentration of total carbohydrates and non-reducing sugar is greater in plants that were harvested in clayey soils and significant (P<0.001) increase values were recorded (total and non-reducing sugars) for plants harvested in 30% sand (Table 4). This group of plants exhibit lower growth in all other aspects and so the reason could be carbohydrate accumulation with no immediate use (Jolly *et al*., 2012). The values for reducing sugars are no more different than other classes of sugars, the significant (P<0.05) increase values were recorded for 20% sand, another factor that comes here in regard is the higher contents of chlorides in clayey soils (Table 4) results in accumulation of reducing sugars both in roots and leaves. The salinity interferes with K+ homeostasis triggering accelerated cell death and reducing growth, but such high contents of reducing sugars are a symptom that *Hordeum vulgare* is a salinity tolerant plant and could produce such high amounts of reducing sugars. Severe drought stresses decrease leaf Relative Water Content (Gupta and Huang, 2014) this meets our results where the lowest values were observed in plants grown on saline soils (with high clay ratios). On the other side, sandy soils offer less drought stress, and significant (P<0.05) increase values of RWC were observed for plants harvested in soils with 100% sand (Table 4). The increased values of leaf water loss were recorded for *Hordeum vulgare* plants harvested in soils with 80% sand and next higher for soil with 90% sand

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Table 4: *Effect of different ratios of sand and clay in soil on reducing, non-reducing sugars, total carbohydrates, relative water content (RWC), Leaf water loss (LWL), and electrolyte leakage (EL) of Hordeum vulgare (L).*

Treatment	Reducing Sugars	Non Reducing Sugars	Total Carbohydrates	RWC	LWL	EL
	(mg/gm fr.wt)	(mg/gm fr.wt)	(mg/gm dry.wt)	%	%	%
100% Sand	0.336abc	0.650ab	0.986ab	94.960b	14.194a	64.305a
	±0.012	±0.03	±0.035	±1.099	±5.149	±45.146
90%Sand+10%Clay	0.303a	1.083c	1.386cd	84.080b	20.868a	80.476a
	±0.013	±0.066	±0.074	±2.658	±9.836	±23.933
80%Sand+20%Clay	0.370abcd	0.943c	1.313cd	86.236b	22.655a	61.586a
	±0.03	±0.083	±0.053	±3.244	±3.431	±40.646
70%Sand+30%Clay	0.310ab	0.863bc	1.173bc	94.866b	12.422a	59.137a
	±0.01	±0.171	±0.177	±0.373	±1.558	±49.648
60%Sand+40%Clay	0.383bcd	0.896bc	1.280cd	93.076b	13.042a	87.245a
	±0.031	±0.016	±0.02	±3.685	±5.982	±19.599
50%Sand+50%Clay	0.356abcd	0.850bc	1.206bc	89.436b	11.748a	40.838a
	±0.029	±0.112	±0.103	±3.932	±4.569	±22.21
40%Sand+60%Clay	0.400cd	0.846bc	1.246c	83.306b	10.833a	51.242a
	±0.023	±0.024	±0.006	±1.709	±1.782	±8.704
30%Sand+70%Clay	0.390bcd	1.383d	1.773e	91.293b	10.583a	79.386a
	±0.005	±0.08	±0.076	±1.206	±4.605	±36.095
20%Sand+80%Clay	0.426d	1.060c	1.486d	43.606a	12.521a	51.253a
	±0.044	±0.037	±0.006	±22.32	±0.967	±33.126
10%Sand+90%Clay	0.333abc	0.880bc	1.213bc	90.633b	10.321a	26.790a
	±0.023	±0.009	±0.013	±1.743	±2.312	±9.241
100% Clay	0.386bcd	0.433a	0.820a	72.040b	15.627a	25.656a
	±0.006	±0.006	0.000	±10.501	±5.319	±0.003
$LSD_{0.05}$	0.101	0.053	0.054	0.086	0.132	0.23
Probability Level	P<0.05	P<0.001	P<0.001	P<0.05	NS	NS

Means followed by different letters in the same column differ significantly at the 95% probability level according to New Duncan's Multiple Range Test.

(Table 4) rest of the values stayed in a range that no difference in their population means was observed (Naveed *et al*., 2014). Electrolyte leakage refers to membrane permeability increased by severe drought stress in this regard in our results the lower values were recorded for plants harvested in soils with high ratios of clayey soils.

Conclusions and Recommendations

The present research was conducted to investigate soil proportions and composition of different growth attributes of the *Hordeum vulgare*crop . It was observed that soil physical and chemical properties led to changes in different growth parameters of Barley and maximum growth was observed in terms of number of leaves, branches, fruits, plant height, proteins, because chlorophylls contents were significantly (P<0.05) increased in proportion towards sandy soils. However, the soil analysis moisture, hygroscopic water, pH, cation exchange capacity (CEC), chlorides, organic matter were found significantly (P<0.05) increased in other soil combinations. Therefore, the present study recommends that *Hordeum vulgare* should be grown in sandy soil proportion for its better growth and productivity as compared to other proportions which are less favorable for its growth.

Novelty Statement

The current research was conducted out to analyze the effect of different ratios of sand and clay composition on the biochemical, physiological and morphological aspects of Barley (*Hordeum vulgare* L.) in relation with the variations in soil physical and chemical properties.

Author's Contribution

Humaira Gul and Rabia Khan: Conducted the research and drafted the initial manuscript.
Mamoona Rauf: Conducted Statistical analyses
Muhammad Junaid Yousaf and Fawad Ali: Conducted the conceptualization, validation of the study and construction of figures.
Alia Gul and Farhad Ali: Critically reviewed and edited the manuscript.

Conflict of interest
The authors have declared no conflict of interest.

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