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Research Article

Influence of different types of soils on the growth and yield of Quinoa (*Chenopodium quinoa* Wild.)

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Abstract
Quinoa is a resilient high-yielding pseudo cereal, gaining attention because of its high nutritional value, strong growth potential, and tremendous source of essential amino acids, micronutrients, vitamins, phenolic compounds, and minerals. The main aim of this investigation was to find the best suitable soil type for maximizing the growth and yield of Quinoa. The pot study was undertaken at the Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, during the Kharif 2022 season. Eight soil samples (clay loam soils of wetlands of TNAU, sandy loam soils of eastern block of TNAU, sandy loam soils of Mettupalayam, sandy clay loam soils of 36 B eastern block of TNAU, sandy clay loam soils of 37 B eastern block of TNAU, clay loam soils of Ooty, sandy clay loam soils of Govindanaickenpalayam and sandy clay loam soils of Annur) were collected round Coimbatore in Tamil Nadu and tested in a complete randomized design with three replications. The pot study results revealed that growth parameters *viz.* Plant height (81.5 cm), number of leaves plant^{-1} (164.8), leaf area (317.7 cm^2), number of branches plant^{-1} (38.0) and dry matter production (22.78 g) were significantly higher in the clay loam soils of Ooty than all other soil types. Similarly, yield attributes such as the number of panicles plant^{-1} (21.7), panicle length (13.08 cm), number of grains panicle^{-1} (3050) and grain yield plant^{-1} (9.60 g) of Quinoa were also higher in the same clay loam soils followed by that in sandy clay loam soils of Govindanaickenpalayam. Red soils of Mettupalayam had shown the lowest growth, yield and yield attributes of Quinoa. Based on the above results, it was concluded that the clay loam soil of Ooty was the best suited for cultivating Quinoa crops.

Keywords: Grain yield, Growth characters, Quinoa, Soil types, Yield attributes

INTRODUCTION

In recent years, the cultivation of pseudo cereals such as grain Amaranth, Quinoa, Canihua and Buckwheat are gaining importance due to attractive nutritive values. Among the pseudo cereals, Quinoa has emerged as a fascinating crop for research, production and consumption in the United States, Europe, Asia and Africa (Gupta and Morya, 2022). It originated in the Andean regions of the Americas and belonged to the family *Amaranthaceae* / *Chenopodiaceae* (Karina *et al.,* 2014). It is the most widely grown crop, with a global cultivation area of 126 thousand hectares and with an average production of 103 thousand tonnes. It is grown in 440 hectares in India with a productivity of 1053 kg ha^{-1}, mostly in Rajasthan. Recently, it has been cultivated in isolated pockets in Karnataka, Tamil Nadu and Andhra Pradesh (Srinivasa Rao, 2015). It has been observed to have a tolerance to a wide range of abiotic stresses and had a prominent role in the future diversification of the agriculture system in India (Ramesh *et al*., 2017). As compared to cereals and legumes, Quinoa contains rich source of nutrients with high protein (10-18%), carbohydrates (67-74%) and crude fat (4.5-8.5%) content (Sukhmandeep and Navjot, 2017).

Soil types are the important factors affecting the growth characteristics of crop species. Different soil types have different physico-chemical characteristics, affecting the flow and accumulation of water, fertilizer, gas and heat in the soil, affecting crop growth and yield (Loriana *et al.,* 2020). Ideal soil conditions are necessary to increase crop performance. In addition to providing physical support, soil also serves as a supply of water and nutrients, which are essential for crop growth (Feng *et al.,* 2022). An essential first step in raising crops is understanding the relationship between soil types and the growth and development of specified crops (Zhao *et al.,* 2015). Hence, in this study, the performance of Quinoa was investigated with different soil types that were widely dispersed in the surroundings of Coimbatore.

MATERIALS AND METHODS

A pot experiment was undertaken in the Department of Agronomy, Tamil Nadu Agricultural University (TNAU), Coimbatore, Tamil Nadu, during *Kharif* 2022 season (June-September). This investigation was laid out in a completely randomized design with eight different soil types gathered from different areas around Coimbatore, Tamil Nadu. The places from where the soils were collected are mentioned below as treatments.

T_1-Clay loam soils of wetlands of TNAU
T_2-Sandy loam soils of eastern block of TNAU
T_3-Sandy loam soils of Mettupalayam;
T_4-Sandy clay loam soils of 36 B eastern block of TNAU
T_5-Sandy clay loam soils of 37 B eastern block of TNAU
T_6-Clay loam soils of Ooty;
T_7-Sandy clay loam soils of Govindanaickenpalayam
T_8-Sandy clay loam soils of Annur

The soils were collected from the top 50 cm layer of the fields at representative sites. The soil types and their characteristics are given in Table 1. Each pot was filled with 6 kg of air-dried soil, and 20 seeds of Quinoa were sown on the surface of the soil and covered with a thin layer of soil. The seedlings were thinned to six plants per pot at 5-6 leaf stage. The pots were arranged randomly during the investigation. No fertilizers were supplied to pots to assess the impact of different types of soils on quinoa production. Water was given as required. Leaf area and the number of leaves plant^{-1} were measured at the flowering stage. The crop was harvested at the physiological maturity of the crop. Plant height, number of branches plant^{-1}, dry matter production, number of panicles plant^{-1}, panicle length, test weight, number of grains panicle^{-1} and grain yield plant^{-1} were accounted for at the maturity stage with standard procedure. The collected data were subjected to statistical analysis (Gomez and Gomez, 2010).

RESULTS AND DISCUSSION

Soil characteristics

The physical and chemical properties of the soil used in this trail are shown in Table 1. The texture of the soil collected from the wetlands of TNAU and Ooty is clay loam in nature, whereas it is sandy loam for the Red soils of the eastern block of TNAU and Mettupalayam. The soils obtained from 36 B eastern block of TNAU, 37 B eastern block of TNAU, Govindanaickenpalayam and Annur were sandy clay loam texture. The pH of the soils ranged from slightly alkaline to moderately alkaline (7.91-8.79) except for the Ooty soils, which were acidic in nature (4.90). The salinity of the soils used in this investigation ranged from 0.17-0.96 dSm^{-1}, categorized as non-saline. The organic carbon of the soils collected from wetlands of TNAU, Red soils of the eastern block of TNAU, Red soils of Mettupalayam and 37 B eastern block of TNAU are low in nature, whereas it was medium in the case of other soils except for Ooty soils which is with high organic carbon. The available nitrogen content of all the soils is categorized as low (<280 kg ha^{-1}) except for the clay loam soils of Ooty, which have a moderate amount of available nitrogen (376 kg ha^{-1}). The soils of Ooty registered a high amount of available phosphorus, but the remaining soils had medium available phosphorus. All the soils used in this experiment were high in available potassium. The analytical results indicated that the clay loam soils of Ooty are inherently more fertile when compared to other soils. This could be attributed to balanced amounts of sand, silt and clay fractions, moderate quantity of available nitrogen, and high concentrations of organic carbon, phosphorus and potassium. Similar findings were realized by Shanmugasundaram and Savithri (2000). Sandy loam soils of Mettupalayam had low soil fertility, possibly due to high fractions of sand and unbalanced concentrations of NPK in the soils.

Plant height

The experimental results indicated that the plant height of Quinoa was significantly affected by different soil types. The tallest plants of Quinoa were noticed with treatment T_6 (clay loam soils of Ooty), which was significantly higher than other treatments but was found comparable with T_4 (Sandy clay loam soils of 36 B eastern block of TNAU) treatment (Table 2). An increase in plant height with Ooty soils could be ascribed to the higher initial nutrient status of the soils, which will have

Table 1. Physico-chemical properties of the different types of soils around Coimbatore

Treatments	Textural class	Physical properties				Chemical properties					
		Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	pH	EC (dSm^{-1})	Organic carbon ($g\ kg^{-1}$)	Available N ($kg\ ha^{-1}$)	Available P ($kg\ ha^{-1}$)	Available K ($kg\ ha^{-1}$)
T_1	Clay loam	45.40	12.70	23.00	17.90	7.91	0.57	4.50	201.2	12.00	424.3
T_2	Sandy loam	18.40	17.16	23.78	38.62	8.55	0.17	4.60	222.6	16.20	473.5
T_3	Sandy loam	17.70	18.70	36.54	26.23	8.13	0.15	4.10	154.4	15.30	451.6
T_4	Sandy clay loam	32.50	10.60	38.60	17.93	8.48	0.96	5.70	255.0	10.50	481.7
T_5	Sandy clay loam	29.09	16.69	30.64	23.11	8.79	0.18	4.30	166.0	18.00	550.0
T_6	Clay loam	38.20	26.20	27.80	4.70	4.90	0.55	59.8	376.0	33.16	631.0
T_7	Sandy clay loam	35.40	9.40	37.10	17.85	8.15	0.23	5.80	260.0	10.90	392.0
T_8	Sandy clay loam	36.70	19.87	35.50	7.93	8.35	0.21	5.60	245.0	12.40	372.0

T_1-Clay loam soils of wetlands of TNAU; T_2-Sandy loam soils of eastern block of TNAU; T_3-Sandy loam soils of Mettupalayam; T_4-Sandy clay loam soils of 36 B eastern block of TNAU; T_5-Sandy clay loam soils of 37 B eastern block of TNAU; T_6-Clay loam soils of Ooty; T_7-Sandy clay loam soils of Govindanaickenpalayam; T_8-Sandy clay loam soils of Annur

a favourable impact on cell division and enlargement, which is eventually reflected in the height of the plant. Bashir *et al.* (2022) stated that the highest growth of soybean was noticed in sandy clay loam soils along with a balanced supply of NPK. The shortest plants were realized in the sandy loam soils of Mettupalayam (Table 2), which might be due to the poor available N within the soil.

Number of branches and dry matter production plant^{-1}

There existed a significant variation in the number of branches and dry matter production plant^{-1} of Quinoa tested under different soil types. The clay loam soils collected from Ooty (T_6) recorded a significantly higher number of branches and dry matter production plant^{-1} over all other soils tried, barring treatments T_8, T_2 and T_1 (Table 2). Improvement in these growth parameters in the Ooty soils was mainly due to the balanced nutrient content and maintenance of optimum soil moisture in the soils due to better texture that resulted in greater accumulation of carbohydrates, proteins and their translocation to the different plant parts, which in turn improved these parameters of Quinoa. The lowest number of branches and dry matter production plant^{-1} was noted in the sandy loam soils of Mettupalayam (Table 2). Other studies reported similar effects of balanced nutrients for higher biomass production in various crops (Akamine *et al.,* 2007; Hossain *et al.,* 2011; Akamine *et al.,* 2021).

Number of leaves plant^{-1} and leaf area

Data on the number of leaves plant^{-1} and leaf area of Quinoa as influenced by different soil types had shown significant variation at the flowering stage of the crop. Higher number of leaves plant^{-1} and leaf area of Quinoa were accounted for with clay loam soils of Ooty when compared with that of other treatments (Table 2). But these parameters were found comparable in the soil types collected from 36 B eastern block of TNAU (T_4), Annur (T_8), eastern block of TNAU (T_2) and wetlands of TNAU (T_1). The increase in the number of leaves plant^{-1} and leaf area of Quinoa in the Ooty soils was mainly due to higher amounts of organic carbon and nitrogen, whose efficient utilization has resulted in better vegetative development of the crop. A significant increase in leaf area with an increase in nitrogen levels was reported by Kakabouki *et al.* (2019). Sandy loam soils of Mettupalayam produced the lowest number of leaves plant^{-1} and leaf area of Quinoa at the flowering stage (Table 2) due to poor soil fertility.

Panicle characters

Variations in panicle characters differed significantly due to different soil types. The number of panicles plant^{-1} and panicle length of Quinoa was recorded to be

Table 2. Effect of soil types on growth characteristics of Quinoa

Treatments	Plant height (cm)	Number of branches plant^{-1}	Number of leaves plant^{-1}	Leaf area (cm^2)	Dry matter production (g)
T_1	54.1	25.0	89.2	133.9	9.27
T_2	60.0	26.7	98.3	150.6	10.34
T_3	39.2	15.3	43.2	53.8	3.98
T_4	81.1	32.3	103.9	158.5	14.10
T_5	46.7	19.7	61.4	102.5	5.78
T_6	81.5	38.0	164.8	317.7	22.78
T_7	72.2	35.0	117.6	184.9	17.09
T_8	63.1	29.0	99.7	155.6	12.01
SEm±	2.3	0.9	4.0	8.5	0.58
CD (P=0.05)	7.1	2.6	12.1	25.8	1.75

T_1-Clay loam soils of wetlands of TNAU;T_2-Sandy loam soils of eastern block of TNAU;T_3-Sandy loam soils of Mettupalayam;T_4-Sandy clay loam soils of 36 B eastern block of TNAU;T_5-Sandy clay loam soils of 37 B eastern block of TNAU;T_6-Clay loam soils of Ooty;T_7-Sandy clay loam soils of Govindanaickenpalayam;T_8-Sandy clay loam soils of Annur

significantly higher with the clay loam soils of Ooty (Table 3). However, these parameters were on par in the sandy clay loam soils of Annur (T_8) and sandy loam soils of the eastern block of TNAU (T_2). The rise in panicle characters with the clay loam textured Ooty soils might be due to the high fertility status of the soils compared to other soils. Akamine *et al.* (2021) reported that the combined application of NPK has resulted in a higher yield of amaranthus than other fertilizer treatments. The lowest panicle characters were reported with the sandy loam soils of Mettupalayam (Table 3).

Grain characters

The soils collected from different areas significantly influenced the number of grains panicle^{-1}. A higher number of grains panicle^{-1} was counted with the clay loam textured Ooty soils than other soil types (Table 3). This might be due to the efficient use of inherent soil nutrients that played a crucial role in the improvement of grain characteristics of Quinoa. The treatments T_8 and T_2 maintained non-significant disparity in the number of grains panicle^{-1} of Quinoa. Razzaghi *et al.* (2012) reported the highest seed number m^{-2} of Quinoa in sandy clay loam soils of Denmark. Sandy loam soils of Mettupalayam resulted in the lowest number of grains panicle^{-1} of Quinoa due to poor availability of nutrients. No significant variation was observed with regard to test weight of Quinoa as influenced by different soil types (Table 3). The test weight of crops is a genetic character and does not influence with different soil types.

Grain yield

A significant variation due to different soil types was found in the grain yield plant^{-1} of Quinoa. Among the various soils tried, significantly higher grain yield plant^{-1} was recorded with clay loam textured soils of Ooty than

Table 3. Effect of soil types on yield attributes of Quinoa

Treatments	Number of Panicles plant^{-1}	Panicle length (cm)	Test weight (g)	Number of grains panicle^{-1}
T_1	12.7	4.42	1.85	1200
T_2	14.9	5.54	1.86	1569
T_3	7.6	2.04	1.62	278
T_4	16.8	7.57	1.95	1933
T_5	10.3	3.27	1.72	818
T_6	21.7	13.08	2.02	3050
T_7	18.8	8.64	1.89	2193
T_8	15.0	5.90	1.88	1719
SEm±	0.6	0.34	0.05	69
CD (P=0.05)	1.7	1.02	0.14	210

T_1-Clay loam soils of wetlands of TNAU;T_2-Sandy loam soils of eastern block of TNAU;T_3-Sandy loam soils of Mettupalayam;T_4-Sandy clay loam soils of 36 B eastern block of TNAU;T_5-Sandy clay loam soils of 37 B eastern block of TNAU;T_6-Clay loam soils of Ooty;T_7-Sandy clay loam soils of Govindanaickenpalayam;T_8-Sandy clay loam soils of Annur

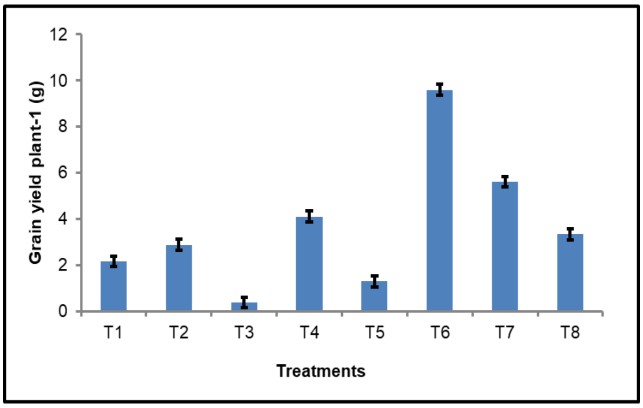

Fig 1. *Grain yield plant^{-1} (g) as influenced by different soil types (T_1-Clay loam soils of wetlands of TNAU;T_2-Sandy loam soils of eastern block of TNAU;T_3-Sandy loam soils of Mettupalayam;T_4-Sandy clay loam soils of 36 B eastern block of TNAU;T_5-Sandy clay loam soils of 37 B eastern block of TNAU;T_6-Clay loam soils of Ooty;T_7-Sandy clay loam soils of Govindanaickenpalayam;T_8-Sandy clay loam soils of Annur)*

Fig. 2. *Showing Quinoa growth at 70 DAS due to different types of soils (T_1-Clay loam soils of wetlands of TNAU;T_2-Sandy loam soils of eastern block of TNAU;T_3-Sandy loam soils of Mettupalayam;T_4-Sandy clay loam soils of 36 B eastern block of TNAU;T_5-Sandy clay loam soils of 37 B eastern block of TNAU;T_6-Clay loam soils of Ooty;T_7-Sandy clay loam soils of Govindanaickenpalayam;T_8-Sandy clay loam soils of Annur)*

others, but it was found at par with the treatments T_8 (sandy clay loam soils of Annur) and T_2 (sandy loam soils of eastern block of TNAU) (Fig.1). Higher yield response of Quinoa in the Ooty soils might be due to favourable soil texture, chemical properties of soil and adequate supply of nutrients such as nitrogen, phosphorus and potassium which resulted in improvement in growth parameters which in turn improved the yield of Quinoa. Razzaghi *et al.* (2012) recorded the highest seed yield of Quinoa in sandy clay loam soils. The lowest grain yield plant^{-1} of Quinoa was observed in the sandy loam soils of Mettupalayam (T_3) (Fig.1). Stagnation was observed immediately after application of water in the sandy loam soils of Mettupalayam and the soil was compact when dried that resulted in reduced soil aeration and nutrient absorption which ultimately have a negative impact on the yield of Quinoa. Ohshiro *et al.* (2016) reported a higher yield of Amaranthus in the grey soils of Nishihara, Japan.

Conclusion

The present study revealed a significant variation in the growth and yield characteristics of Quinoa. Among eight soils (clay loam soils of wetlands of TNAU, sandy loam soils of eastern block of TNAU, sandy loam soils of Mettupalayam, sandy clay loam soils of 36 B eastern block of TNAU, sandy clay loam soils of 37 B eastern block of TNAU, clay loam soils of Ooty, sandy clay loam soils of Govindanaickenpalayam and sandy clay loam soils of Annur) tested, clay loam textured soils collected from Ooty recorded significantly higher growth, yield attributes and yield of Quinoa followed by sandy clay loam soils of Govindanaickenpalayam. Soils collected from Mettupalayam registered the lowest growth and yield characteristics in Quinoa. The study revealed that soil's physical and chemical characteristics, along with fertility status, influence the production of Quinoa.

Conflict of interest

The authors declare that they have no conflict of interest.

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