D-5735
[1-6]

RESEARCH ARTICLE Agricultural Science Digest, Volume Issue : ()

Effect of Soil Types on Phenology and Heat Units of Quinoa

S. Mobeena[1], N. Thavaprakaash[2], K. Vaiyapuri[1], M. Djanaguiraman[1], S. Geethanjali[1], P. Geetha[1], S.P. Sangeetha[1]

10.18805/ag.D-5735

ABSTRACT

Background: Quinoa, a promising pseudocereal crop has superior nutritional profile and able to withstand wide range of biotic and abiotic stresses. Understanding the effect of different soil types on phenology and heat units is important in new crop like quinoa. Therefore, in this investigation, different soil types that widely dispersed around Coimbatore were used to evaluate the performance of quinoa on its phenology and further heat units.

Methods: Pot experiment was carried out in the Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore during *Kharif* 2022 season. Eight soil types were collected from different areas around Coimbatore and tested in completely randomized design with three replications. Development of phonological stages were noted and in turn calculated heat units by using standard formulae.

Result: Results of the investigation revealed that clay loam textured Ooty soils took maximum days to attain four phenological stages, *viz*., branching, panicle initiation, flowering and physiological maturity of quinoa than other soils. Similarly, more heat units (Growing Degree Days, Helio Thermal Units, Photo Thermal Units and Relative Temperature Disparity) were recorded with the soils collected from Ooty when compared to other soils. Sandy loam soils of Mettupalayam registered the least number of days to attain different developmental stages and also recorded the lowest heat units of quinoa. Based on the above results, it can be concluded that among eight different soils, the growth of quinoa was prolonged in clay loam textured Ooty soils and correlation with yield indicated that extending duration enhanced the yield.

Key words: Heat units, Phenology, Quinoa, Soil types, Yield.

INTRODUCTION

Quinoa (*Chenopodium quinoa* Willd.) is an herbaceous annual crop originated from Andean regions of South America. It is primarily grown in Bolivia and Peru and are major producers and exporters of quinoa in the world. It has earned a lot of attention worldwide owing to its unique nutritional and health benefits and its potential to adapt to contrasting environments, such as nutrient-poor, saline and sodic soils and drought stressed marginal agro ecosystems (Hinojosa *et al*., 2018). Apart from high protein content, quinoa is rich in essential amino acids such as lysine, methionine and threonine; micronutrients, vitamins, phenolic compounds and minerals (Egritas *et al*., 2022). The antioxidant level of quinoa is five times higher than those of cereal flours and also abundant in linoleic and linolenic fatty acids. In addition to being used as food for humans, quinoa seed is also used as livestock and poultry feed. Owing to its balanced nutritional benefits, the year 2013 has been declared as an international year of quinoa by United Nations (Choudhary *et al*., 2020).

Beyond climate, soil characteristics such as soil physical and chemical properties are believed to play an important role in plant growth, influencing the availability of air, nutrients and water (Loriana *et al*., 2020). Crop yield and soil have a complicated relationship that depends on the physical and chemical characteristics of the soil as well as other external natural influences (Juhos *et al*., 2015). Soils differ in their draining, water retention capacity and nutrient solubility and availability with inevitable consequences which decides the survival and performance of many crop species.

[1]Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil Nadu, India.
[2]ICAR-Krishi Vigyan Kendra, Virudhachalam-606 001, Tamil Nadu, India.

Corresponding Author: N. Thavaprakaash, ICAR-Krishi Vigyan Kendra, Virudhachalam-606 001, Tamil Nadu, India.
Email: thavaprakaash.n@tnau.ac.in

How to cite this article: Mobeena, S., Thavaprakaash, N., Vaiyapuri, K., Djanaguiraman, M., Geethanjali, S., Geetha, P. and Sangeetha, S.P. (2023). Effect of Soil Types on Phenology and Heat Units of Quinoa. Agricultural Science Digest. doi:10.18805/ag.D-5735.

Submitted: 01-02-2023 **Accepted:** 05-05-2023 **Online:** 05-06-2023

Determining phenology especially for a new crop in a particular region is important to understand the behaviour of the crop. It also aids in creating reliable information to support breeding and agronomical research programmes (Zuniga *et al*., 2017). Calculating different heat units during the crop growth allows for the estimation of different phenological events and timing of harvest of the crop (Parthasarathi *et al*., 2013). Apart from that the information regarding suitability of a region for production of a particular crop and effect of heat stress on crops can also be estimated through accumulated heat units.

Understanding how different soil types affect the growth, development and phenology of particular crops is important and this can be studied through accumulated heat units.

Quinoa is a newly evolved pseudo cereal and had a great potential in India and hence, it is utmost important to determine attainment of phenological stages. Therefore, in this investigation, the influence of different soil types on phenological development and accumulated heat units of quinoa were evaluated.

MATERIALS AND METHODS

A pot experiment was conducted in the Department of Agronomy, Tamil Nadu Agricultural University (TNAU), Coimbatore during *Kharif*, 2022 season. Eight different soils were collected from different areas around Coimbatore district which was laid out in completely randomized design with three replications. The places from where the soils collected were 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 used in the trail were collected from eight different representative locations at a depth of 50 cm layer of the fields. Before the start of the trail, each soil sample was sieved through 2mm sieve and were taken to laboratory for physical and chemical analysis (Table 1). The pots were filled with 6 kg of air dry soil and arranged randomly during the investigation. Each pot was sown with 20 seeds of quinoa and covered with thin layer of soil. At 5-6 leaf stage, the seedlings of quinoa were thinned in order to reduce competition. To evaluate the true effect of various soil types on quinoa production, no fertilizers were added to the pots. Water was given as required for proper germination and crop growth. Crop phenology (branching, panicle initiation, flowering and harvest stage) of quinoa was recorded as per the stage development descriptions of Zuniga *et al.* (2017). During the crop season, the daily data on prevailed temperature and bright sunshine hours were collected from Agro-climatic Research Centre, TNAU, Coimbatore. The details of the day length were obtained from Rastriya Panchang (Anonymous, 2022-23) published by Positional Astronomy Centre, IMD, Kolkata. The heat units were calculated as follows:

$$GDD = \sum_{i=1}^{n} \frac{[Tmax + Tmin]}{2} - Tb$$

(Iwata, 1984)

$$HTU = \sum_{i=1}^{n} GDD \times BSSH$$

(Rajput, 1980)

$$PTU = \sum_{i=1}^{n} GDD \times \text{Day length}$$

(Major *et al*., 1975)

$$RTD = \sum_{i=1}^{n} \frac{[Tmax - Tmin]}{Tmax} \times 100$$

(Rajput, 1980)

Where,
GDD - Growing degree days.
HTU - Helio thermal units.
PTU - Photo thermal units.
RTD - Relative temperature disparity.
Tmax - Maximum temperature (°C).
Tmin - Minimum temperature (°C).
Tb - Base temperature = 3(°C).
BSSH - Bright sunshine hours.

The collected data were subjected to statistical analysis and correlation was worked out between heat units and grain yield of quinoa as suggested by Gomez and Gomez (2010).

RESULTS AND DISCUSSION

Soil characteristics

The physical and chemical properties of soils were analyzed in the laboratory and the results have been given in Table 1. Soils collected from eastern block of TNAU and Mettupalayam were sandy loam in texture whereas, clay loam texture was observed in wetlands of TNAU and Ooty soils. The texture of the soils gathered from 36 B eastern block of TNAU, 37 B eastern block of TNAU, Govindana ickenpalayam and Annur were sandy clay loam. Except Ooty soils, which are acidic in character (4.90), the pH of the soils varies from slightly alkaline to moderately alkaline (7.91-8.79) in all other soils. The soils used in this trail had electrical conductivity (EC) ranging from 0.17-0.96 dSm^{-1}, which are considered to be non-saline in nature. The clay loam textured Ooty soils registered the highest amount of organic carbon whereas, it is medium and low in soils collected from Govindanaickenpalayam, Annur and 36 B eastern block of TNAU. The rest of soils had low organic carbon content. All the collected soils have low available nitrogen content (<280 kg ha^{-1}), with the exception of the clay loam soils in Ooty, which have a moderate amount of available nitrogen (376 kg ha^{-1}). The Ooty soils had high levels of available phosphorus, whereas the other soils had medium levels of available phosphorus. All the soils used in this trail are rich in available potassium. The results of the laboratory analysis indicated that the clay loam textured Ooty soils are highly fertile over other soils. This might be due low fractions of sand and appropriate amount of silt and clay with balanced nutrient levels. These findings are in line with the findings of Shanmugasundaram and Savithri (2000). The lowest soil fertility was recorded in sandy loam soils of Mettupalayam could be due unbalanced sand, silt and clay fractions with low concentration of nutrients.

Phenophases development

Soils collected from different areas had shown significant impact on days required to attain phenophases of quinoa (Table 2). Among eight different soils tested, clay loam textured Ooty soils required the maximum number of days to attain different developmental stages (branching, panicle initiation, flowering and physiological maturity) of quinoa.

The delay in each developmental stage of quinoa in clay loam soils of Ooty was mainly due to higher fractions of clay and organic carbon content that could facilitate greater uptake and assimilation of available nutrients which promotes the vegetative growth and also favours delayed leaf senescence, sustained leaf photosynthesis during grain filling period and had a direct impact on phenology of the crop. Ahmad *et al.* (2008) reported that availability of

Table 1: Physico-chemical properties of the soils used in the experiment.

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.

Table 2: Effect of soil types on phenology of quinoa.

Treatments	Days to branching stage	Days to panicle initiation stage	Days to flowering stage	Days to maturity stage
T_1	26.67	35.33	53.67	81.33
T_2	27.00	35.67	54.33	85.00
T_3	23.33	32.33	48.00	72.33
T_4	28.00	36.33	56.00	89.67
T_5	25.67	34.67	51.00	75.67
T_6	30.00	39.00	59.00	97.67
T_7	27.67	37.00	56.00	93.33
T_8	27.33	36.00	55.33	86.33
SEm±	0.48	0.60	0.82	1.09
CD (P=0.05)	1.47	1.82	2.47	3.29

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.

Table 3: Effect of soil types on growing degree days (GDD) values of quinoa.

Treatments	Branching stage	Panicle initiation stage	Flowering stage	Harvest
T_1	660.9	856.6	1297	1952
T_2	668.2	864.1	1313	2039
T_3	604.8	788.9	1176	1738
T_4	690.2	879.2	1351	2153
T_5	638.1	841.4	1237	1819
T_6	735.1	941.4	1395	2316
T_7	683.0	894.5	1351	2215
T_8	675.5	871.7	1336	2072
SEm±	10.9	13.8	19	25
CD (P=0.05)	32.9	41.8	57	76

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.

nutrients with good soil conditions promotes the duration of wheat crop. Delay in physiological maturity of quinoa was observed with increase in nitrogen levels from 0 to 125 kg N ha^{-1} (Basra *et al*., 2014). Sandy loam soils of Mettupalayam registered the minimum number of days to attain all developmental stages of quinoa due to poor availability of nutrients. The correlation between different developmental stages *viz*., branching, panicle initiation, flowering and physiological maturity and grain yield was positive and significant (0.90**, 0.94**, 0.89** and 0.93**, respectively) and indicates delay in attaining different phenophases favours the grain yield of quinoa.

Growing degree days

Growing degree days (GDD) required to complete each phenophase of quinoa varied in different soil types (Table 3). The clay loam textured Ooty soils required higher GDD to attain different developmental stages of quinoa when compared to other soils tried. This was mainly due to favourable soil texture with balanced nutrients that leads to a longer period for all phenological stages in turn increased the accumulated growing degree days of quinoa. Rathore *et al.* (2019) recorded higher GDD with longer growing period of quinoa. Sandy loam soils of Mettupalayam took the least GDD to complete each phenophase of quinoa due to shorter maturity period. Correlation between GDD and grain yield showed positive and significant relation (0.92**) which indicated that GDD had positive influence on yield of quinoa.

Helio thermal units

The amount of helio thermal units (HTU) to attain individual phenological stages of quinoa varied with different soil types (Table 4). Helio thermal units required to attain all the developmental stages of quinoa were higher in clay loam textured Ooty soils over other soils. This might be due to more time taken for attaining phenological stages under Ooty soils which accumulated maximum growing degree days and sunshine hours in turn increased the helio thermal units. Sikder (2009) reported highest helio thermal units with wheat cultivars of more duration. The lowest heat units (HTU) were

Table 4: Effect of soil types on helio thermal unit (HTU) values of quinoa.

Treatments	Branching stage	Panicle initiation stage	Flowering stage	Harvest
T_1	3836	4258	6644	10039
T_2	3840	3025	6803	10445
T_3	3792	4051	5771	9120
T_4	3846	4349	6841	11233
T_5	3828	4177	6126	9476
T_6	3937	4617	6875	12096
T_7	3844	4397	6841	11450
T_8	3844	4314	6822	10707
SEm±	11	21	24	115
CD (P=0.05)	35	65	72	347

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.

Table 5: Effect of soil types on photo thermal unit (PTU) values of quinoa.

Treatments	Branching stage	Panicle initiation stage	Flowering stage	Harvest
T_1	7930	10279	15477	23426
T_2	8018	10369	15676	24476
T_3	7281	9466	14178	20861
T_4	8282	10550	16217	25838
T_5	7657	10097	14776	21829
T_6	8821	11297	16749	27804
T_7	8196	10734	16217	26591
T_8	8106	10460	16034	24872
SEm±	107	120	147	301
CD (P=0.05)	324	365	447	912

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.

Table 6: Effect of soil types on relative temperature disparity (RTD) values of quinoa.

Treatments	Branching stage	Panicle initiation stage	Flowering stage	Harvest
T_1	711.9	878.4	1327	1988
T_2	717.9	885.4	1346	2079
T_3	660.8	817.4	1195	1759
T_4	733.9	896.7	1379	2201
T_5	693.8	863.4	1250	1848
T_6	772.6	952.9	1437	2357
T_7	728.8	908.2	1379	2258
T_8	724.0	889.6	1365	2115
SEm±	8.9	12.5	17	26
CD (P=0.05)	27.0	38.0	53	80

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.

noticed with sandy loam soils of Mettupalayam. A positive and significant correlation (0.94**) was found between HTU and grain yield of quinoa indicates increased HTU was favouring the quinoa yield.

Photo thermal units

Heat units in terms of photo thermal units (PTU) to pass each developmental stage varied under diverse soil types (Table 5). Among the different soils tried, the Ooty soils with clay loam in texture registered higher heat units (PTU) to attain different developmental stages of quinoa than all other type of soils under testing. Days required to attain the phenological stages of quinoa were higher under Ooty soils and also higher growing degree days directly influenced the PTU values. The least photo thermal units were observed in sandy loam soils of Mettupalayam. Correlation between PTU and grain yield was positive and significant (0.92**) and indicated a positive relationship.

Relative temperature disparity

With different soil types, there was a variation in relative temperature disparity (RTD) at all the developmental phases of quinoa (Table 6). Clay loam soils collected from Ooty recorded more relative temperature disparity at all phenological phases of quinoa when compared with that of other soils. As the RTD values depend on maximum and minimum temperature experienced during phenophases, the crop grown on Ooty soils took more days to pass individual phenophase, accumulated more RTD values. Thavaprakaash *et al.* (2007) recorded higher RTD values with late *Rabi* sown baby corn crop with more duration. Sandy loam soils of Mettupalayam recorded the lowest values of RTD values at all developmental phases of quinoa. The correlation was worked out between RTD and grain yield of quinoa and it was positive and highly significant (0.92**) which indicated a positive association.

CONCLUSION

The present investigation concludes that there was a significant effect on phenology and heat units (GDD, HTU, PTU and RTD) of quinoa due to different soils types. More number of days to attain each developmental stages and higher values of heat units of quinoa was recorded with the clay loam textured Ooty soils over other soils tested. The least days to attain different phenological phases and lower values of heat units of quinoa were recorded with sandy loam soils of Mettupalayam. The correlation between phenophases and yield indicated positive relationship. The study revealed that the soil characteristics and fertility status of the soil had strong impact on phenology and heat units of quinoa.

Conflict of interest: None.

REFERENCES

Ahmad, K., Mohammad, T.J., Muhammad, A., Khan, B.M. and Amanullah, J. (2008). Phenology and crop stand of wheat as affected by nitrogen sources and tillage systems. Pakistan Journal of Botany. 40(3): 1103-1112.

Anonymous, (2022-23). Rastriya Panchang. Published by the Director, Positional Astronomy Centre, IMD, Kolkata.

Basra, S.M.A., Iqbal, S. and Afzal, I. (2014). Evaluating the response of nitrogen application on growth, development and yield of quinoa genotypes. International Journal of Agriculture and Biology. 16(5): 886-892.

Choudhary, J., Sharma, S.K. and Kumar, R. (2020). Consequence of fertility levels and row spacing on growth, yield and economics of quinoa (*Chenopodium quinoa*) under saline-sodic soil conditions of Southern Rajasthan. Journal of Pharmacognosy and Phytochemistry. 9(4): 1204-1206.

Egritaş, O., Tan, M. and Haliloglu, K. (2022). Identifying some morphological features of mutant quinoa plants (*Chenopodium quinoa* Willd.). Legume Research. 45(7): 815-821.

Gomez, K.A. and Gomez, A.A. (2010). Statistical Procedures for Agricultural Research. Edition. New Delhi, India: Wiley India Pvt Ltd.

Hinojosa, L., Juan, A.G., Felipe, H.B., Francisco, F. and Kevin, M.M. (2018). Quinoa abiotic stress responses: A review. Plants. 7: 106. https://doi.org/10.3390/plants7040106.

Iwata, F. (1984). Heat Unit Concept of Maturity. In: Physilogical aspects of dry land farming, [Gupta U.S. (Ed)], Oxford and IBH, New Delhi, pp: 351-370.

Juhos, K., Szabo, S. and Ladanyi, M. (2015). Influence of soil properties on crop yield: A multivariate statistical approach. International Agrophysics. 29: 433-440.

Loriana, C., Donato, C., Michele, P., Laura, S., Nunzia, C. and Vincenzo, C. (2020). The Influence of soil physical and chemical properties on saffron (*Crocus sativus* L.) growth, yield and quality. Agronomy. 10: 1154.

Major, D.J., Johnson, D.R., Tanner, J.W. and Anderson, I.C. (1975). Effect of day length and temperature on soybean development. Crop Science. 15: 174-179.

Parthasarathi, T., Velu, G. and Jeyakumar, P. (2013). Impact of crop heat units on growth and developmental physiology of future crop production: A review. Research and Reviews: A Journal of Crop Science and Technology. 2(1): 1-11.

Rajput, R.P. (1980). Response of Soybean Crop to Climatic and Soil Environments. Ph. D. Thesis, IARI, New Delhi, India.

Rathore, S., Bala, M., Gupta, M. and Kumar, R. (2019). Introduction of multipurpose agro-industrial crop quinoa (*Chenopodium quinoa*) in western Himalayas. Indian Journal of Agronomy. 64(2): 287-292.

Shanmugasundaram, R. and Savithri, P. (2000). Apprisal of soil nutrient of Nilgiris district of Tamil Nadu. Madras Agricultural Journal. 87(9): 507-509.

Sikder, S. (2009). Accumulated heat unit and phenology of wheat cultivars as influenced by late sowing heat stress condition. Journal of Agriculture and Rural Development. 7(1and2): 57-64.

Thavaprakaash, N., Jagannathan, R., Velayudham, K. and Gurusamy, L. (2007). Seasonal influence on phenology and accumulated heat units in relation to yield of baby corn. International Journal of Agricultural Research. 2(9): 826-831.

Zuniga, V.S., Brito, V., Fuentes, F. and Steinfort, U. (2017). Phenological growth stages of quinoa (*Chenopodium quinoa*) based on the BBCH scale. Annals of Applied Biology. 170(2): 8. doi:10.1111/aab.12358.