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Growth and Yield of Quinoa Crop at different periods in the Telangana Region

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Abstract: Quinoa is a highly nutritious and gluten-free crop. In the context of climatechange, it is a good grain substitute crop. Due to inadequate precipitation and high temperatures around the flowering period, late seeding of quinoa stunted plants and lowyields in thedesert region ofMorocco(Rehamna). Short-cyclecultivarsshould besown early in order to maximise growth and yields. In order to learn more about how the sowing date affects quinoa growth, development, and yield, a field experiment was carried out in thesemi-arid regions in 2018-2019. The main aim of this research is to identify the best-fit sowing period.In order to evaluate Quinoa (Chenopodium Quinoa Willd) at various dates of sowing intervals in semi-arid regions of Telangana, a field experiment was carried out at Ghapur village during Rabi 2018–2019. Two sowing dates were used that is December 15th and December 1st. Quinoa showed greater growth, yield, and yield qualities on December15th when it was sown with 30 cm × 30 cm spacing, the dibbling sowing technique, RDF:100 kg N, 50 kg P_2O_5, 50 kg K_2O ha^{-1}.A significant difference in both seed yield and a delay in phenological phases, related to plant maturation and flowering.

Keywords: Quinoa, Chenopodium Quinoa Willd, Sowing, Semi-Arid Region, Telangana,and Dibbling Method.

INTRODUCTION

Quinoa (Chenopodium Quinoa Willd) is a dicotyledonous plant that mostly grows in South

America in the Andes, including Bolivia, Peru, Argentina, Colombia, and Chile. It belongs to the Amaranthaceae family. Currently, it is grown on every continent. Quinoa is a C3 plant with high levels ofdrought andfrost enduranceas well assalinitytolerance, makingit ideally suited to the challenging circumstances of the Andean highlands (Alvar-Beltrán, *et al* 2019). Sinceityieldsagrain-likeseedthatcanbeusedinsoups,bread,andotherusesormarketedas whole grain and it is regarded as a pseudo-cereal. In other words, it's a seed that has been processed and prepared into the grain.Quinoa is mostly grown for its edible seeds, which are used in human food. The evaluation of seed performance was a vast majority of agronomic research on the plant.However, (Temel, S, *et al* 2020) studied sowing and harvesting times in quinoa grown for hay production are almost non-existent. In the studies carried out, it was revealed that seed performances were significantlyaffected bysowing and harvestingperiods and, as a consequence, sowing or harvesting should be carried out at an early or late period. The 15th October date of sowing, 15 cm × 10 cm spacing, dibbling method of sowing, RDF:100 kg N, 50 kg P_2O_5, 50 kg K_2O ha-1, recorded the higher growth, yield and yield attributes of quinoa. The drip method of irrigation recorded higher yield and yield attributes than the surface method of irrigation (Ramesh, *et al* 2019).

Although quinoa is cultivated for its seeds, it is also grown for its hay as a source offodder (Taaime, N, *et al* 2022). The plant can produce high herbage yields and quinoa hay is especially preferred by cattle (FAO, 1994). Moreover, the seed content is 10 to 18 % protein (higherthanmaizeandwheat),4.50to8.75%crudefat,54.10to64.20%carbohydrates,and 2.40 to 3.65% (Prajapati, *et al* 2022). Because of such properties, quinoa can be viewed to have a great potential for benefiting from production in marginal areas, overcoming the roughage gap and supplying the daily nutritional requirements of animals. However, (Rabbani, *et al* 2022) determine the effects of planting date and planting density on quinoa seed yield in climatic conditions of Kermanshah.In order to obtain the desired yield and quality performances in the quinoa plant grown for hay production purposes, it is necessaryto establish appropriate sowing and harvesting periods according to the ecological conditions of the region where it will be grown (Rashid, *et al* 2021).Seeds of quinoa genotype UAF-Q7 were sown at the Research Area of the Directorate of Farms, University of Agriculture, Faisalabad-Pakistan. All the foliar treatments significantly improved the physiological and growth attributes (Rashid, N, *et al* 2022).

In (Talebnejad, *et al* 2022), planting quinoa (Chenopodium quinoa)under different irrigation regimes and planting dates was investigated. Irrigation regimes included full irrigation (FI) and 50% of full irrigation (0.5FI), where planting dates consisted of six plantingdates in theearlyspringandsix plantingdates in theearlyfall. Results indicated that the highest grain yield, dry matter, root dry weight, leaf area index, harvest index, and yield components were obtained in early spring cultivation on February 19 and in the early fall on August 23 planting dates (Karami, *et al* 2020).In India, quinoa was cultivated in an area of

440hectareswithanaverageyieldof1053tons.SinceitsIndependence,Indiaexperiencedagreen revolution (rice & wheat), a white revolution and is still India tops in chronic malnutrition (Singh, *et al* 2022).A very high per cent population was suffering from diabetes due to over-dependence on a few cereal foods (rice or wheat) (APARD, 2013-14). Quinoa isa good source of food with high nutritional and medicinal values especially amino acids,high-quality protein content, vitamins, minerals etc. are twice the normally consumed cereals (Biswas, *et al* 2020). It can be introduced in India to check malnutritionaswell as to increase foreign exchange. Quinoa includes a range of varieties, adapted to different agricultural systems and climatic conditions, including salinity and drought, and adapts to sandy and marginal soils that are poor and poor (AL-asadi, *et al* 2021). Quinoa is considered a strategic crop with higher potential in contributing to food and nutritional security due to higher nutritional quality, genetic variability, adaptability to adverse climate and soil conditions and economically low production cost or cultural adaptability to the Indian farming system (Kadam, *et al* 2018).

The quinoa crop is usually grown on poor fertility soil and moisture is the limiting factor forgrowthanddevelopment(Wang, *etal*2020). Undertheseconditions,anoptimumnutrient supplement is necessary to minimize the effects of soil nutrient status and to promote good plant growth. However, quinoa is highly responsive to soil nitrogen. Therefore, it becomes more important to find out the variations with respect to different plant densities and nutrient management in relation to its growth and productivity (Naik, *et al* 2020).(Adamczewska-Sowińska, *et al* 2021) conducted on two soils: medium (clay soil texture) and light (sand soil texture), sowing quinoa in spring and summer periods. On both soils, quinoa was harvested 5 times at each sowing date. The yields of fresh plant biomass, basic morphological characteristics and certain quality traits were compared. Harvesting date had the greatest effect on the change in nutritional values.(Asher, *et al* 2020) investigated quinoa cultivation for grain (seed) production and cattle feeding in Israel. Six quinoa accessions were sown in northern Israel at two different winter dates for two years using a scarce amount of irrigation. Quinoahayandstrawqualitywerehighascrudeproteinconcentrationreached19.9%and 10.6%, respectivelywith an in vitro DMdigestibility(IVDMD)of 75.8% and 54.2 %.

The quantity and quality of the hay obtained from the plants grown for fodder production are directly related to the sowing and harvesting times (Taaime, *et al* 2022). Although variations can be seen as to the ecological conditions of the region of cultivation, in general, increases in hay yields and decreases in nutritional values have been determined with the progress of the development period in plants (Sandepogu, *et al* 2022). Moreover, in early sowing,plantsstayinthefieldforalongertime,comparedtolate-sownplants,andbenefitfromtheenvironmentalconditionsinanoptimumway.Asaconsequence, yieldsmaybehigh while the qualityvalues are low. However, studies on which the sowing and harvesting times were tested together in the quinoa plant grown for hay production purposes were almost nonexistent in the world and Turkey. It was reported in a few studies conducted on thesubject that quinoa hay yield and quality were significantly affected by sowing andharvesting periods (Srinivas, *et al* 2018).(Casini, *et al* 2019) aimed at identifying the correct sowing period. (Shoman, *et al* 2018) showed that the effect of sowing dates on all studied parameters was significant except, the number of inflorescence/ plant, carbohydrates % and oil % don't affect significantly by sowing dates during the two growing seasons. The sowing date on 1st December had the highest values for all studied traits as compared with the rest dates during the two growing seasons.

The field experiment was conducted during the rabi (winter) season of 2018-19 at the Agricultural Research Station, Mandor, Jodhpur (Ram, *et al* 2021). The crop geometry didnot influence the maturity days of quinoa. It was concluded that quinoa crops can be sown between 15th November and 25th November with a plant geometry of 30 cm x 30 cm for higher seed yield in western Rajasthan.To investigate the effects of nitrogen application rate and split application method on the growth and yield of quinoa, a split plot experiment was conducted in a randomized complete block design with three replications during the two cropping seasons of 2018 and 2019. (Ebrahimikia, *et al* 2021) showed that nitrogen fertilization delayed the flowering and increased the length of the seed-filling period, plant height, photosynthetic pigments content, number of seeds per plant, seed yield, and aboveground biomass compared to nitrogen-free conditions.Although it has been shown that thesowingandharvestingperiodsofquinoadifferaccordingtotheregions, itcanbesaidthat few studies conducted on the subject are inadequate, since sowing and harvesting periodsmay significantly vary as to the ecological conditions of the cultivation regions. In addition,to what degree yield and quality properties of quinoa cultivated for hay production purposes affected by different sowing and harvesting periods must be completely cleared out. In this respect, such studies on quinoa are important to determine optimum yield and quality performance under different sowing periods. Consequently, a research study was planned to determine appropriate sowing periods. Therefore, the experiment was conducted at Ghapur village, during Rabi 2018-19 to evaluate Quinoa (Chenopodium Quinoa Willd.) at different dates of sowing intervals at semi-arid regions of Telangana, two sowing dates were implemented: 1st December: 15th December for achieving high hay yield and quality properties. The restofthepapersareorganizedasfollows,section2revealsthe materialsandmethod, section 3 portrays the result and discussion section, and section 4 illustrates the conclusion of the work.

1. MATERIALSANDMETHODS

The study was conducted between 2018 and 2019 at Ghanpur village, in the farmer field, geographically experimental site is situated inthe Warangal district, South Agro-climatic region of Telangana. The soil was moderately blocky on the surface and sandy loam intextureslightlyalkalineinreaction(7.8),averageavailablesoilmoisturein0-60cmwas 96.2 mm, the main objective of this study was to identify the best-fit sowing period since the crop introduced to India recently, The field experiment was conducted at Ghapur village, during Rabi 2018-19 to evaluate Quinoa (Chenopodium Quinoa Willd.) at different dates of sowing intervals at semi-arid regions of Telangana, two sowing dates were implemented: 1st December: 15th December.

QuinoainIndia

In India 65% population was dependent on agriculture, though more than 50% population practised it was very difficult to feed the rapidly growing population, hence India used to import some of the food grains from other countries, but during the 1966-67 green revolution played an important role on the Indian agriculture sector especially rice and wheat, the dwarf gene varieties of rice and wheat were introduced from Mexico to India for the higher cereal production. Pulses and oil seed crops, soybean for proteins and sunflower for oil seeds were introduced from China and America respectively into India though the traditional varieties were cultivated their yields were recorded as low due to higher pest and disease incidence. Similarly, it is the right time to introduce a crop like quinoa in India to check some of the health problems faced by the Indian population.

1.1 Product Preparation

The study was conducted between 2018 and 2019 inthe Warangal district, South Agro-climatic region of Telangana. When some climatic data of the experimental area were examined, average temperature values of the growing season of 2017 and 2018 were measured as 18.2^{o} C and 19.5^{o} C, relative humidity 72% and 52.8%, total rainfall amounts were 252.8 mm and 141.7 mm, respectively. According to the long-year average, average temperature, relative humidity and total precipitation amount are measured as 18.41^{o} C, 48.6%and166.4mm,andthe soilmoisture in0-60cm was96.2mmrespectively.According

to thesedata, theexperiment was conductedunderrelativelymorearid conditions sincelower precipitation was observed according to long-years averages in the cultivation period within which the research was conducted.

Figure1: SampleImages

Figure 1 represents the sample images of Quinoa (Chenopodium Quinoa Willd). Adequate amounts of soil samples (0- 30 cm) were taken in both research years and according to the results of the analyses, it was found that soils were found to be non-saline, slightly alkaline, with mild lime content, low available phosphorus level and high potassium content.However, the experiment site in 2017 had a clay-loam soil structure with a good organic matter content, while the 2018 research site was classified as clay soil with medium-level organic matter content.

1.2 AgroTechniquesforHigherProductivityofQuinoa

The climatic requirement, land preparation, sowing methods, irrigation, and harvest management are presented in this section.

ClimaticRequirements

Quinoa adapts to desert, hot and dry climates. This crop can survive in a wide range of temperatures from - 4°C to 40°C. It is tolerant to low soil moisture with precipitations from 100 to 200 mm. It can be grown from sea level to elevations of 4000 meters altitude.

SoilType

It is a hardy crop that can grow in the low fertile soil of rainfed areas. Well-drained soil particularlysandyloamisgoodtogrowquinoa.Itcanthriveonalkalinesoils(uptopH9.0) and acid soils (up to pH 5.0) with a liberal application of lime. Soil should have high in organic matter with average nutrient contents.

Land Preparation

Quinoa requires a well-pulverized seed bed with fine tilth for good germination of seed and establishment of the desired plant stand. Land preparation should be done with MB plough followedbysecondarytillagewithdisc harrow andcultivator (criss-cross) toensurefine tilth. The land should be perfectly levelled to ensure that there is no water logging.

Varieties

Quinoa is a new crop and improved varieties are not available in India. No report is available so far on its breeding programmes.

SeedRateandSowingMethod

Seedshouldbea sowwiththehelpofsmallhand-operatedseederunits or byhandat25to30 cm row-to-row spacing and 10 to 15 cm of plant-to-plant spacing. The optimum seed rate is 15-20 kg seed per hectare. The depth of planting varies with soil type and is usually 3-5 cm. Uniform depth of planting ensures regular emergence and crop growth, thus facilitating subsequent intercultural operations. The seed rate and seed size are small, seeds are mixed with sand or ash to increase the volume handled to assist even distribution of seeds.

DatesofSowingandSeedRate

Very little research work has been done on the adaptability and standardisation of thepackage of practices of quinoa in India. The genetic variability and adaptation in North India reported that entries originated from inter-Andean valleys of Bolivia that are white or yellow with small size are more adaptable than other entries. Optimum planting time is the first step and is considered a base that leads to the development of proper production technology, especially for a new crop in a particular region. Hence, an experiment is proposed entitled “Evaluation of Quinoa (Chenopodium Quinoa Willd.) at different dates of sowing and varied crop geometry in semiarid regions of Telangana”. In this, 3 dates of sowing viz. i.e., D1: 1stDecember, D2: 15thDecember, spacings (30 cm × 30 cm). The dibbling method of sowing, RDF:100 kg N, 50 kg P2O5, 50 kg K2O ha^{-1}, recorded the higher growth, yield and yield attributes of quinoa. A significant difference in both seed yield and a delay in phenological phases, related to plant maturation and flowering.

SowingTime

Sowing is one of the most important activities because of the emergence of seedlings which impacts plant density and final yields. Quinoa seeds are sown from mid-October to mid-November.

MethodofSowing

Healthy, matured and vigorous seeds were used for sowing and seeds were treated sowing was done by mixing seeds with sand and placing 3-4 seeds at an intra-row spacing of 10 cm on three different dates at varied crop geometry. The 20 days old seedlings can be transplanted.The sowing method utilizes the dibbling method. Dibbling is the process of placing seeds in holes made in the seedbed and covering them. In this method, seeds are placed in holes made at definite depths at fixed spacing. The equipment used for dibbling is called a dibbler. It is a conical instrument used to make proper holes in the field.

Irrigation

Water management is very important for quinoa cultivation in the initial 20-30 days of the crop. If irrigation is not provided the crop will show wilting symptoms and result in lower yields. It is better to give irrigation by drip method if possible. The research was conductedon irrigation with different treatments and concluded that the drip method of irrigation recorded higher yield and yield attributes compared to other irrigation methods. In order toget optimum yield under irrigated conditions, 5-6 irrigations are sufficient, depending on the climatic conditions. If water is limited and available only for 4 irrigations; it may be appliedat different growth stages via.Panicle initiation, flowering, seed forming and seed hardening stages.

WeedControl

Slowinitial growthduringthefirst two weeks afteremergenceand widerspacingprovides an ideal environment for weeds to grow and compete with the crop. There are no registered pre-emergence and post-emergence herbicides for controlling weeds in quinoa crops at this time.

PlantProtection

Pest and disease problems may arise after a crop like quinoa is introduced to a new area. In case of any sign or symptom of diseases or pests plant protection measures are followed. However,iftimely sown,managedproperlyandharvested.Plantprotectionmeasuresarenot required.Commonpestsarecauseddamagetocropsincludestemborers,aphids,fleabeetles, beet armyworms and leafhoppers. During December and January when the crop attains luxuriant vegetative growth and cloudy days persist for a longer period, the heavy infestation of fungal diseases such as dumping off, gray mould, powdery mildew and leaf spot occurs.

Harvest Management

Plantshavesorghum-like seedheadsatmaturity. Harvestusuallybeginswhentheplantshave dried,turnedapale yelloworred colourandleaveshavedropped.Theplantswereallowed to dry in the threshing yard for 3 to 7 days. The threshing of the plants was done separately by beating them with sticks. The crop can be harvested either manually with the help of a sickle or combined with a sorghum header. A fanning mill and gravity separator are usually necessary to remove trash from the seed after combining.

Table1: GeneralAgronomicPractices-FromTransplantingtoHarvesting)

CropStage	**Window**	**DAT**	**Operations**
Nursery	-15	-15/18	MainFieldpreparations: FYM(CowDung)
Transplanting	0	0	TransplantingSSP100KG,25KGPotash(If directsownmethod)
Seedling	00-08	3	Gapfilling
Seedling	08.-15	15	IstTopdressing (Manure)
Tillering	16-23	23	IstWeeding,UreaApplication
Tillering	23-37	37	IInd Topdressing
Priboot	37-50	50	IIWeeding,HighIrrigation(Water)
Boot	50-60	60	
Pre-Flowering	60-70	70	Nickingadj, IstRouging
Flowering	70-79	79	Rouging
Dough	79-104	104	Roughing
Harvesting	104-115	115	Harvesting
Drying			HighSunlight
Threshing			ManualorMachine
Storage			RoomTemperature

Table1 represents the General Agronomic Practices,which consistof cropstage,window, DAT and their operations. The crop stage is a nursery, transplanting, seedling, Tillering, Pri boot, Boot, Pre Flowering, Flowering, Dough, Harvesting, Drying, Threshing, and storage. The nursery presents the window values of -15 and their operations are Main Field preparations: FYM (Cow Dung). The window and DAT for transplanting are 0, and the transplanting operation is Transplanting SSP 100KG, 25KG Potash (If direct sown method). However,seedling consists ofthewindowas00-08 and08-15, theirDATis 3 to 15,andtheir operationsareinGap fillingand I^{st} Topdressing(Manure). Accordingly, Tilleringconsists of the window as 16-23 and 23-37, 23 and 37, and the operations are I^{st} Weeding, Urea Application and II^{nd} Top dressing. For the crop stage Pri boot, the window is 37-50 and their DATare50,however,theiroperationis IIWeeding,HighIrrigation(Water).Thewindowfor Boot is 50-60 and DAT is 60. When the crop stage is Pre-Flowering, their window and DAT are 60-70 and 70, their operation is nicking adj, I^{st} Rouging. The window and DAT for flowering are given as 70-79 and 79, and their operation is roughing. Subsequently, for the crop stage dough, the window and DAT are 79-104 and 104, and their operation is roughing. Accordingly, for the crop stage harvesting, the window and DAT are 104-115 and 115, and their operations are harvesting. For drying, threshing, and storage stages, they are operated under high sunlight, manual or machine, and at room temperature, respectively.

EffectonCrop

Plant population per unit area was markedly influenced by different methods of sowing. The dibbling method of sowing maintained a uniform plant population compared to the broadcasting method. Dibbling the seeds three days after the pre-sowing application of paraquat @ 0.5 kg ha^{-1} recorded higher values of plant height (36.4 cm and 34.8). This effect was reflected in producing taller plants.

The conventional method of one manual weeding at 20 DAS was inferior to theapplication of PoE herbicides to obtain increased crop growth parameters. This might be due to the growth of weeds up to one manual weeding at 20 DAS and subsequent rejuvenation of weeds registered in traditional manual weeding practices. However manual weeding maintained its superiority over unweeded checks in obtaining increased crop growth parameters.

CropSeedYield

The interaction effect between methods of sowing and weed management practices on seed yield was significant. The average seed yield of the crop is about 1400-2100 kg/ha inirrigated conditions and 600-700 kg/ha in rainfed situations.

1.3 Measurements

The growth, development, and yield of quinoa are generally affected by both cultivars and climatic conditions. In this study, the field experiment was conducted at Ghanpur village, in the farmer field; the geographically experimental site is situated in Warangal district, South Agro-climatic region of Telangana. Excluded two rows of each side of the experimental unit from all measurements and the following growth parameters were assessed.

PlantHeight

The plant height was measured from the base of the plant at ground level to the growing tipof the plant (base of the top leaf) at 30 DAS, 60 DAS and harvesting stage. Plant height and vegetative development are positively correlated to yield. Thus, the height of ten plants from thecentreofthe experimentalplot wasmeasured bi-weeklystartingtwomonthsafter sowing. The number of leaves, panicles, and branches per plant as well as their dry matter were also measured. After the emergence of the panicle, the height was taken up to the base of the panicle on the main shoot. The average plant height was worked out and expressed in centimetres.Plant height increased with a delayed sowing date in 2018; however, in 2019, plant height increased with a delayed sowing date only from December 15th to April 10thand decreased with delaying sowing date from April 10th to December 1st. The highest plant height (4003) was obtained for trail 1A and the plant height for trail 1B is represented as 3830.29.The delay in the planting date led to the collision of the vegetative stage withoptimalgrowthtemperatureconditions (15°C to 25°C) andconsequentlyincreasedvegetative growth. Whereas in early planting dates, plant exposure to low-temperature conditions leads to plant stress exposure, and therefore in the path of shortening the vegetative phase andfaster entry into the reproductive phase and plant height decreases.In addition, studies on quinoa have reported that plant height varies depending on environmental conditions, resulting in a decrease in plant height with delayed planting dates.

PanicleLength

The effects of years, sowing dates, planting densities, genotypes, and their interactions, were significant for panicle length. Panicle length increased with a delayed sowing date from December 15th to April 10th and, decreased with delayed planting from April 10th to December1stin2019butincreasedwithadelayedsowing datefromDecember15thtoApril

10th in 2018 to 2019. The highest panicle length was obtained with a sowing date of December 15th. The lowest panicle length was obtained with the sowing date of December 1st. The highest (42.8 cm) and lowest (31.1 cm) panicle lengths were recorded for the Valiente genotype on December 15th for planting dates, respectively.

SeedNumbers/Plant

The number of seeds per plant was significantly affected by year, sowing dates, planting densities, genotypes, and their interactions. Delayed sowing from December 15th to April 10thincreasedseednumbersperplantand thenfromApril10thtoDecember1stdecreasedin 2019. Thehighest seed yield andseed protein are represented as23.13 and 20.16 for trail 1A, and 26.29 and 19.44 for trail 1B.

SeedWeight/Plant

The effects of years, sowing dates, planting densities, genotypes, and their interactions were significant for seed weight/plant. The seed size for trail 1A is 0.14 and the seed size for trail 1B is represented as 0.15. Seed weight/plant increased with delayed sowing date from December 15th to December 1st in both years, with no significant difference between April 10th and December 1st sowing dates. The highest seed weight/plant was recorded with the sowing date of December 15th. The quinoa was sown in the respective plots using the seed rate of 5 kg/ha and thinning was done after two weeks of sowing to maintain plant spacing of 45 cmX10 cm (Singh, *et al* 20202). The crop was irrigated 4 times during the crop season as and when crop plants showed moisture deficiency (drooping of leaves in the afternoon). The observations on growth parameters like plant height and dry weight were recorded at 30, 60 and 90 DAS. The grain and stover yields were recorded at harvest.

SeedYield

The effects of year, sowing dates, planting densities, genotypes, and their interactions were significant for seed yield. Delaying planting in both cases increased seed yield in 2019; however, in 2018 it increased when the sowing date was delayed from December 15th to April 10th and decreased with the delayed sowing date from April 10thtoDecember 1st. The highest seed yield (26.29) was achieved, respectively. It seems that the reason for increasing seed yield on the second trial dates is the optimum temperature on December 1st, causing faster plant growth, more vigorous plants, and higher seed yield. The delayed planting reduced the yield of the Andean region, due to the limited plant life cycle bytemperature and photoperiod. Increasing planting density caused increased seed yield in both years. The present study showed that the increase in seed yield per area was mainly attributed to branchingreductionatthehigherplantdensity,andtherefore,ahigherproportionofseed yield has been produced from the main panicle while lower plant densityled to an increase in plant branching.

Harvest Index

The effects of years, sowing dates, planting densities, genotypes, and their interactions were significant for the harvest index. In this study, the harvest index decreased with the delayed sowingdatesinthe2019 growingseason andnosignificantdifferencesbetweensowingdates were observed in the 2019 growing season. The highest harvest index (0.35) was obtained by trail 1B, and the lowest harvest index (0.32) was obtained by trail 1A.

TotalNumberof Branches

From randomlyselected plants, a total number ofbranches were counted at 30 DAS, 60 DAS and the harvesting stage. Data were pooled and the average total number of branches was determined. Therefore, the maximum number of branches or plants is represented as 105.54 for trail 1B, and trail 1A presents the lowest number of plants or branches as 96.12. Accordingly, from randomly selected five plants, the length of the glomerule of the panicle was measured at harvest. Recorded data were pooled and the average length of the glomerule was determined.

DaysTakento Flowering

Dailycounts weremade in eachplot to knowthedays takento 50 percent flowering afterthe vegetative stage. The date on which 50 per cent of the total plants were flowered in each plot was recorded. The number of days taken to 50 per cent maturity was computed from the date of sowing and the mean was expressed as a whole number. The days taken to flowering are86 for trail 1A and 89 for trail 1B.

DaysTakentoMaturity

Daily counts were made in each plot to know the days taken to maturity after the vegetative stage.Thedateonwhich100percentofthetotalplantswerematuredineachplotwas recorded. The number of days taken to 100 per cent maturity was computed from the date of sowingandthemeanwasexpressedasawholenumber.Thenumberofdaystakento maturity is 95 for trial 1A, and the number of days taken to maturity is 559.12 for trial 1B. **Field Emergence (%)**

Field emergence was calculated by sowing 100 seeds in 4 replications with 5 cm spacing between the seeds. The number of seeds that germinated and seedlings that emerged within the field was counted on the 10th day after sowing. The field emergence was calculated by using the following formula.

$$\text{FieldEmergency}(\%)=\frac{\text{NumberofSeedlings Emerged}}{\text{TotalNumberofSeeds Sown}}\times 100 \quad (1)$$

InflorescenceLength

Days to emergence, dicotyledonous leaves, two, four, and six true leaves, panicle emergence, flowering, and maturity were monitored daily on four central lines one meter in length in the differenttreatments.TheInflorescencelengthfortrail1Ais 5.46andthe Inflorescencelength for trail 1B is 5.02.

TotalLeafArea

Leaf area is directly related to the quantity of intercepted light and affects plant productivity. The total leaves of five sampled plants were scanned for two months after sowing. The scan images were analyzed in order to determine the total leaf area. Therefore, the total leaf area for trail 1A is 169.25, and the leaf area for trail 1B is 188.11, respectively.

1.4 Statistical Analysis

Two-way ANOVA analysis was performed for different development stages, CCI, leaf stomatal conductance, plant height, morphological parameters, total leaf area, and yield and its components. Since no major differences were observed between different sowing dates on the plants' physiology and phenology, the sowing dates were combined in two-year experimentation (2017–2018 and 2018–2019). For this reason, sowingdate and year were not considered independent factors, whereas irrigation and N-fertilization were the only independent factors of statistical interest. The analysis of variance (ANOVA) andTelangana's HSD posthoc test were used to estimate the mean variation among and within groups for different crop parameters, as well as to examine the effect of irrigation and N- fertilization and its interaction on a widerange of crop parameters. The ANOVA and Tukey's HSD post-hoc test were done using Minitab 18 and IBM SPSS software. Finally, the Pearson correlation coefficient (*r*) was used to test the association or correlation between two variables.

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AnalysisofCorrelationCoefficients

Acorrelationcoefficienttestwasperformedtoanalysethe correlation betweenvariables.The correlation analysis on different sowing dates determined that panicle length showed a significant positive correlation with seed yield and the biological yield on three sowing dates (December 15th and December 1st); however, there was a significant and negativecorrelation betweenpaniclelength andharvest index in first sowing date (December15th). In (Rabbani, *et al* 2022), has been also found that increasing biomass plays an influential role in increasing the seed yield in quinoa.

2. RESULTAND DISCUSSION

The results significantly show binary interactions were not elaborated separately in the parameters in which triple interactions were found significant, and main factors were not considered separately in the parameters in which binary interactions were significant. The 15th December date of sowing, 30 cm × 30 cm spacing, dibbling method of sowing,RDF:100 kg N, 50 kg P2O5, 50 kg K2O ha^{-1}, recorded the higher growth, yield and yield attributes of quinoa. The results of growth parameters of quinoa viz., plant height at 30, 60 DAS and harvest, number of branches plant-1, the total number of panicles plant-1, days to50 per cent flowering, length of glomerule, days to maturity, field emergence are represented in table 2.

Table2: EffectofDatesofSowingandSpacingInQuinoa

Traits	**Trail 1A**	**Trail 1B**
DaysToFlowering	86	89
DayToMaturity	95	94
Plant Height	4003	3830.29

LeafArea	169.25	188.11
Plant/Branches	96.12	105.54
Inflorescence Length	5.46	5.02
Inflorescence	5196.6	5346.18
SeedSize	0.14	0.15
HarvestIndex	0.32	0.35
SeedYield	23.13	26.29
Seed Protein	20.16	19.44

The analysis of variance showed that the effects of years, sowing dates, planting densities, genotypes, and their interactions were significant for plant height (table 2). The 15th December date of sowing, 30 cm × 30 cm spacing, dibbling method of sowing, RDF:100 kg N, 50 kg P_2O_5, 50 kg K_2O ha-1, recorded the higher growth, yield and yield attributes of quinoa.Asignificant differencein both seed yield anda delayin phenological phases,related to plant maturation and flowering.Dates of flowering and maturity were recorded, at maturity, seed size is 0.14 to 0.15, plat height T1A: 4003 and T1B: 3830.29, Leaf area T1A:169/25 and T1B:188.11, seed protein T1A: 20.16 and T1B: 19.44.

The sowing of quinoa on thermal regimes of 15th November had higher values of plant height, and dry weight at different time intervals (30, 60 and90 DAS) including grain and stover yields at harvest. This might be due to the fact that the 15 November sown crop received the maximum length of the growing period, favourable temperature and other climatological parameters for optimal growth, which alimentally facilitated cell division and cell elongation in compression to 30 November and 15th December thermal regimes of delayed sowing (Singh, *et al* 2022).

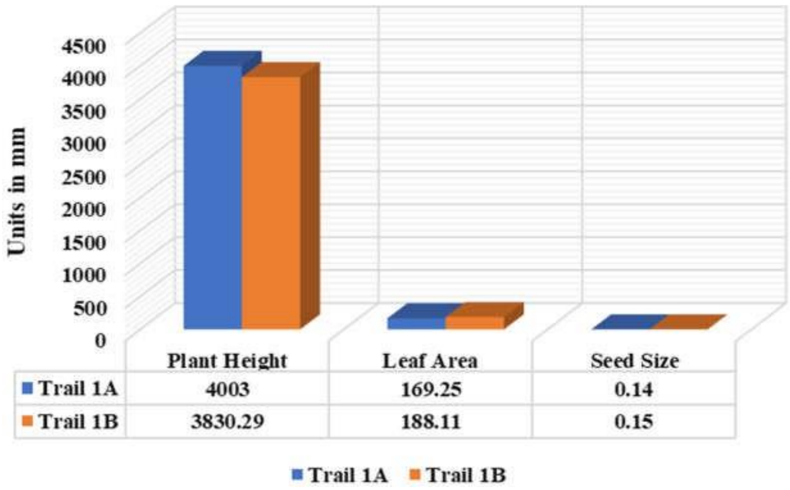

Figure2: PlotforPlant Height,LeafArea,andSeed Size

Figure 2 illustrates the plot for plant height, leaf area, and seed size. The values are expressed for both trail 1A and trail 1B. Accordingly, for trail 1A, the plant height value is 4003mm, and for trail 1B, the plant height value is 3830.29 mm. Subsequently, for trail 1A, the leaf area is 169.25 mm, and for trail 1B, the leaf area is 188.11 mm. However, the seed size for trail 1A is 0.14 mm, and the seed size for trail 1B is 0.15 mm.Ramesh, *et al* 2019 [3] provideaplantheightof 120.7,Rabbani,*etal*portraytheplantheightoftheirworkas113.44 mm, however, the plant height of Singh *et al* illustrates 135.06 mm.

In this study in which different sowing and harvesting times were tested in quinoa plants, the effect of the year 2018 to 2019 sowing time interaction on the plant height was found significant. The highest plant height (4003 mm) was observed in the first trial (T1A) whilethe lowest value (3830.29 mm) was determined in the second trial (T1B). Thetemperature increases shorten the development time of quinoa. Thus, in late sowing, plants may reach harvesting maturity without adequate vegetative development since plants are exposed to increasing temperatures and light intensity. As a result, plant heights in late sowings can be shorter. While the rate of decrease in plant height was quite high from the second sowing to thelast sowingtime.Thefactthat therateofdecreasewas verylow, cause thesignificanceof the year 2019 sowing time interaction. It is considered that changing annual temperatures,and distribution was effective on the differences in plant heights as to sowing times. Hence, environmental factors such as temperature and precipitation played an important role in plant height. Moreover, it was also reported in studies on quinoa that plant height varied according toyearsdependingonchangingclimateconditionsandthatplantheightwasdecreasedwith delays in sowing time.(Temel, *et al* 2020) presents the highest plant height (126.1 cm) was observed in the first sowing (ST1) in 2017 while the lowest value (51.3 cm) was determined in the last sowing (ST4) in 2017.

Among the different nutrient levels and spacings,a significant difference was observed in plant height (Naik, *et al* 2020). At 30 DAS plant height was significantly influenced by different spacing and varying amounts of nutrients at 30 DAS. Among spacing, the highest plantheight(22.57 cm)wasattainedinspacingS4(55x 10cm).Amongdifferent amountsof nutrients, N4 gave a higher plant height of 22.39 cm followed by N3 (21.33 cm) and a lower plantheightwasobservedinN1 (16.80cm).Interactionofbothdifferent spacingandnutrient levels gaveahigherplant height in T12 (S3N4)was (25.91)cm,whereas a lowerplant height was seen in T1 (S1N1) was (12.16) cm. At 60 DAS, the maximum plant height was observed in wider spacing in S3 (45 x10 cm) (110.62 cm) and the least was noticed in narrow spacing S1(25x 10cm)is95.18cm.Therewasanon-significantdifferenceinplantheightat60days after sowing due to different nutrient levels. The highest plant height observed in N3 (125:62.5:62.5 NPK ha^{-1}) is (108.84 cm) whereas the lower plant height observed in N1 (75:37.5:37.5 NPK ha^{-1})is 98.50 cm. Interaction of both spacingand nutrients showed a non- significant difference in plant height, the highest was observed in T12 (S3N4) (119 cm) followedbyS3N3T11 (117.19 cm)whereaslowerplant height wasobserved in T1(S1N1) is
92.36 cm.Theharvest stageshowedsignificantdifferences dueto spacing levels. Thehighest was observed in S3 (45 x 10 cm) (117.93 cm) and the least was observed in S1 (25 x 10 cm) is 100.10 cm. There was no significant difference in plant height at harvest due to different nutrient levels. The highest was observed in N4 (125:62.5:62.5 KgNPK ha-1) is (112.03 cm) whereas lower plant height was observed in N1 (75:37.5:37.5 Kg NPK ha^{-1}) is 102.41 cm. The plant height showed non significantly difference inthe interaction of both spacing and nutrients. Higher plant height was observed in T12 (S3N4) 122.28 cm followed by T16 (S4N4) is 113.82 cm and the lowest was observed in S1N1 (97.90 cm).

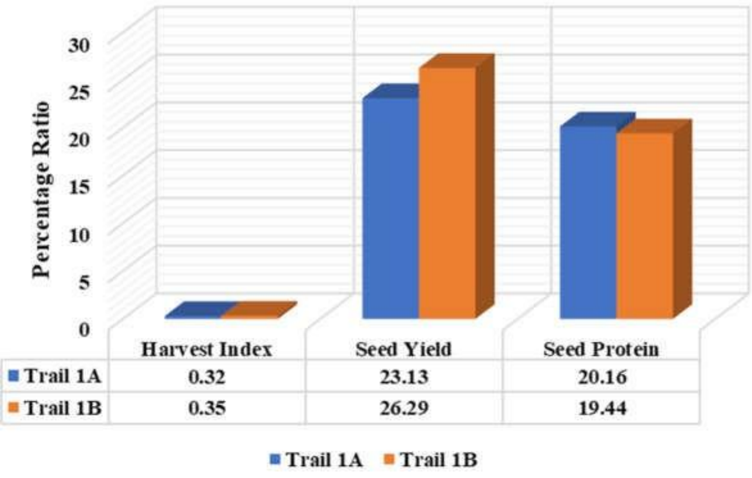

Figure3: Graphfor HarvestIndex, SeedYield, andSeed Protein

Figure 3 reveals the plot for harvest index, seed yield, and seed protein. The harvest index of the work is 0.32% for trail 1A and 0.35% for trail 1B. Accordingly, the seed yield for the proposed work is 23.13%for trail 1A and26.29%for trail 1B. Subsequently, theseed protein for trail 1A is 20.16% and the seed protein for trail 1B is 19.44%.Ramesh, *et al* 2019 [3] provide a seed yield of 26%, and Rabbani, *et al* 2022 [6] present a seed yield of 20.83, respectively. (Reddy, *et al* 2020) presents the seed yield of 22.94 for S4 (45×10 cm).

The harvest index represents the efficient partitioning of assimilates from vegetative parts to the reproductive portion (Madam, et al 2019). The harvest index of all contingent cropswas reduced gradually by delaying the sowing dates. French beans recorded a higher harvest index (0.67, 0.64 and 0.62, respectively) during the August 2nd fortnight, September 1st fortnight andSeptember 2nd fortnight sowings followedbyfieldbean sown in theAugust 2nd fortnight(0.45).Alowerharvestindex(0.26)wasrecordedinfoxtailmilletduringSeptember 2nd fortnight sowing. French bean crop was grown for the vegetable purpose. Due to its high dry matter production and short-duration nature, it was harvested three times, so the harvest index was more for French beans. But foxtail millet and finger millet due to their long duration nature and moisture stress at translocation of food materials from source to sink was greatly affected and recorded less harvest index than other crops.

(Singh, *et al* 2022) portrayed the fertility levels had a marked influence on plant heightand dry weight of quinoa at different time intervals (30, 60 and 90 DAS) including grain and stower yields at harvest. The poor values of growth parameters namely plant height and dry weightincludinggrainandstoveryieldswereobtainedundercontrolplots(N:P:K0:0:0

kg/ha). However, the plant height, dry weight, grain and stover yields were increased correspondingly with increasing fertility levels being the maximum when the Qiunoa was fertilized with 120 N: 60 P2O5:60 K2O kg/ha and proved significantly superior over lower fertility levels. An adequate supply of nitrogen, phosphorus and potassium leads to high photosynthetic activity, vigorous vegetative growth and dark green colour and finally influences the better utilization of carbohydrates and led to record higher values of growth parameters at different time intervals and ultimately had higher grain and stover yields.

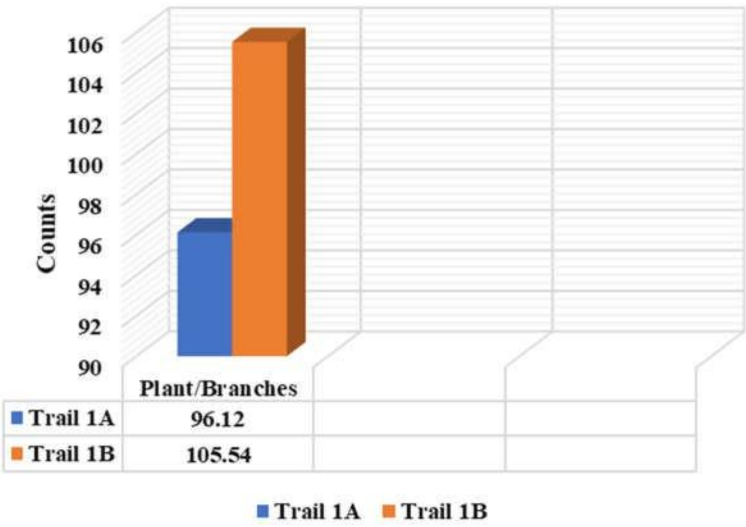

Figure4: Plot for Plant/Branches

Theplot forplants/branchesis presentedin figure 4. It is depictedfortrail 1Aandtrail 1B. Fortrail1A,theplant/branches are96.12,andfortrail1B,theplant/branchespresent105.54, respectively. The total number of branches plant-1 was significantly different as influencedby different levels of spacing. The highest total number of branches observed in S4 (55 x 10 cm) was 15.59 whereas the lower number of branches observed in S1 (25 x 10 cm) was 8.90.Thetotalnumberofbranches wassignificantlydifferentasinfluenced bydifferentlevels of nutrients. The highest total number of branches observed in N4 (150:75:75 Kg NPK ha^{-1}) was 14.57, whereas lower was observed in N1 (75:37.5:37.5 Kg NPK ha-1) was 11.24. The interaction effect of both nutrients and spacing levels has a Non-significant difference in the total number of branches. The highest was observed in T12 (S3N4) is 17.70 followed by T16 (S4N4) was 15.88 whereas the lower number of branches observed in T1 (S1N1) was 6.05.This results conveyed that the total number of branches were more in the higher spacing of45x10cmandnutrientlevelof150:75:75kgNPKha-1becauseofhighernutrientsupply to individual plant and it absorbs more and good plant growth is seen, so more number of branches were seen in (Naik, *et al* 2020).

The total number of panicles plant-1 significantlydiffered with different levels of spacing. The highest number of panicles plant-1 observed in S3 (45 x 10 cm) is 15.22 whereas the lower number of panicles observed in S1 (25 x 10 cm) is 8.47. The total number of panicles plant-1 differed significantly with different levels of nutrients. The highest number ofpanicles observed in N4 (150:75:75 Kg NPK ha-1) is 14.74 whereas the lower in N1 (75:37.5:37.5 Kg NPK ha-1) is 11.51. The interaction effect of both spacing and nutrients on the total number of panicles plant-1 differed significantly. The highest total number of panicles plant-1 was observed in T12 (S3N4) is 17.63 followed by T16 (S4N4) is 15.76 and lower was observed in T1 S1N1 (5.19) (Naik, *et al* 2020).

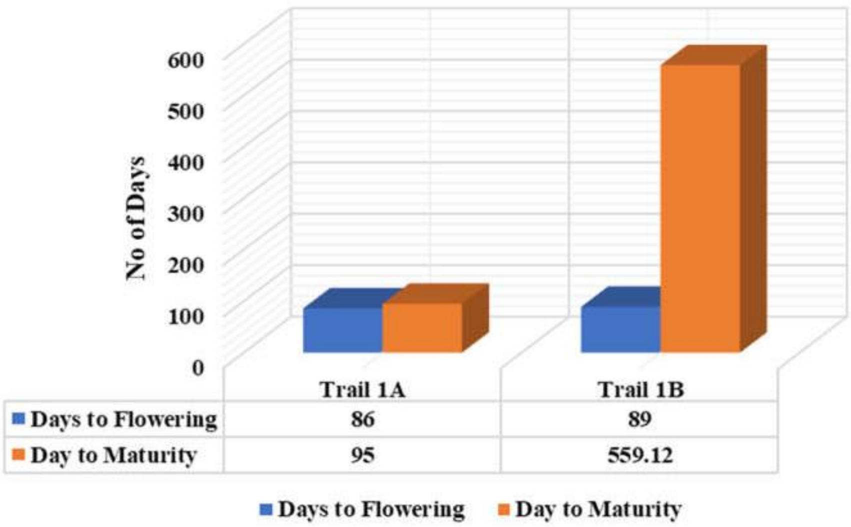

Figure5: PlotforDaysTakenforFloweringand Maturity

The days taken for flowering and maturity are presented in figure 5. It consists of trail 1A and trail 1B. The days to flowering for trail 1A is 86 and for trail 1B IS 89. However, thedays taken for maturity are 95 for trial 1A and 559.12 for trial 1B. Days to 50 percent flowering with different spacing levels show a significant difference. Wider spacing S4 (51.97) took more days and narrow spacing S1 (44.99) took less number of days for 50 per cent flowering (Naik, *et al* 2020). Days to 50 per cent flowering with different nutrient levels showeda non-significant difference. However application of more amount of nutrients. Nutrient level N4 took more days (49.53) and lower nutrient level N1 took less number of days(48.07)for50percentflowering.Interactionofspacingandnutrientsshowedanonsignificant difference for days to 50 per cent of flowering. However higher number of days were taken in S4N4 (52.45) and a lower number of days for 50 per cent flowering is taken in S1N1 (43.65).

Days taken to maturity showed non-significant differences among the spacing treatments. Widerspacing (S4)took 89.32 days andnarrowspacing(S1)took 88.02 days to completethe maturity stage (Naik, *et al* 2020). Days taken to maturity differed non-significantly amongthe nutrient levels. N4 nutrient level took more days (91.22) to complete maturity. Whereas, the N1 nutrient level took fewer days (86.88). The interaction of spacing levels and nutrient levels for days taken to maturity was found to be non-significant for days taken to maturity. The highest number of days (93.45) was taken in S4N4 to complete maturity followed by S3N4 (93.45) and the least number of days (86.50) was taken in S1N1.A statistically significant difference was found by (Naik, *et al* 2020) for the field emergence among the spacing treatments. However, field emergence ranges from 85.75 to 89.17 %. Field emergence was significantly affected by nutrient levels. However, field emergence varies from 85.84 to 89.23 %. Field emergence showed non-significant differences due to the interaction effects of spacing and nutrition. However, the highest field emergence was recorded in S4N4 (91.47 %) and the lowest was observed in S1N1 (84.76 %).

3. CONCLUSION

Quinoa (Chenopodium Quinoa Willd) is one of the most popular emerging food crops in the Andean region. The nutritional qualities of quinoa rich in both proteins and essential amino acids have resulted in increased worldwide demand for quinoa food products and thepotential to contribute to nutrition security in marginal environments. It is tolerant to environmental stresses and characterized by interesting nutritional qualities. The research work conducted an experimental study to evaluate Quinoa (Chenopodium Quinoa Willd) at different dates of sowing intervals at semi-arid regions of Telangana. It was conducted at Ghapur village, during the Rabi 2018-19, two sowing dates were implemented: 15th December:and1stDecember.AmongthedifferentdatesDecember15thandspacings,30cm × 30 cm recorded better results. The proper management practices for quinoa cultivation, and the higher growth, yield and yield attributes of quinoa are recorded. Accordingly, the proposed work is compared with the different existing works. While compare to theseexisting works, the proposed work provides higher plant height and higher seed yield. The results of this experiment showed that planting dates are the most determining factors affectingquinoagrowth,development,andseedyield.Asignificantdifferenceinbothseed yieldandadelayinphenologicalphases,relatedtoplantmaturationandflowering, respectively.

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