QUINOA

(ASHI HEYCHUM)

General Information and Package of Practices

September 2025

Developed and Compiled By: National Center for Organic Agriculture with technical inputs from National Soil Services Center, National Plant Protection Center and Agriculture Research and Development Centers Wengkhar, Bajo and Samtenling

Funded By: The Flexible Voluntary Contributing Project (FVC) on Quinoa (FVC/RAS/209/MUL). Food and Agriculture Organization.

Suggested Citation: Katwal, T.B., Rinzin, C., Uden, T., Zangpo, T., Om, K., & Deki, S. (2025). General Information and Package of Practices of Quinoa. Department of Agriculture. Ministry of Agriculture and Livestock. Thimphu. Bhutan.

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ACRONYMS AND ABBREVIATIONS

AEZ	Agro-ecological Zone
ARDC	Agriculture Research and Development Center
cm	Centimeters
DAMC	Department of Agricultural Marketing and Co-operatives
DoA	Department of Agriculture
FAO	Food and Agriculture Organization
FEFUT	Farmer Extension Fertilizer Use Trial
FVC	Flexible Voluntary Contribution
FYM	Farmyard Manure
FYP	Five-Year Plan
gm	grams
GAP	Good Agricultural Practice
GI	Glycemic Index
HMO	Horticulture Mineral Oil
HP	Horsepower
ICBA	International Center for Biosaline Agriculture
K	Potassium
kcal	kilocalorie
Kg	Kilograms
kW	kilowatt
MC	Moisture Content
mm	millimeters
MoAL	Ministry of Agriculture and Livestock
m asl	meters above sea level
MoP	Murate of Potash
N	Nitrogen
NCOA	National Center for Organic Agriculture
NCT	Nationally Coordinated Trials
NCQP	National Quinoa Commodity Program
NPPC	National Plant Protection Center
NSSC	National Soil Services Centre
PGS	Price Guarantee Scheme
P	Phosphorous
PPM	Parts Per Million
PHS	Preharvest Sprouting
PoP	Package of Practices
RH	Relative Humidity
SSP	Single Superphosphate
UAE	United Arab Emirates
secs	seconds
VRC	Variety Release Committee

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INTRODUCTION

Quinoa (*Chenopodium quinoa Willd*.) is a crop of the Andean region in South America and is mainly cultivated in Bolivia, Chile, and Peru [1]. Quinoa is considered the world's healthiest food. Quinoa has gained popularity due to its exemplary nutritional properties. The Food and Agriculture Organization (FAO) of the United Nations has recognized quinoa as a nutritious cereal and one of the most potential crops that can ensure future food security. The most notable properties of quinoa which make it attractive are its potential to adapt to different types of growing environments, high tolerance to cold, drought and salinity, high nutritional value with high protein content, presence of all nine amino acids, low Glycemic Index (GI) and gluten free.

Further, quinoa is known for its broad genetic diversity which makes it a highly versatile crop that can successfully adapt to different types of growing environments. Quinoa is sometimes referred to as a "pseudocereal" because it is a broadleaf non-legume plant that is grown for grain, and its seeds are used as that of true cereals like wheat and rice. In addition, quinoa does not belong to the grass family. Quinoa is considered as a strategic crop by FAO to contribute significantly to global food security due to its high nutritional quality, genetic variability, adaptability to adverse climate and soil conditions, and low production cost [2].

Quinoa was introduced to Bhutan from Peru in 2015 by the Department of Agriculture (DoA) with the support of the FAO [3]. Quinoa is known for its high nutritional quality, genetic variability and versatility to adapt to adverse climate and soil conditions. The underlying objectives of introducing and adapting Quinoa in Bhutan is to increase the on-farm crop diversity; adapt this versatile crop to different growing environments as a climate resilient crop; and to enhance the food and nutritional security of the Bhutanese people through the consumption of this nutritious crop. In addition, prepare and develop this crop as a special export commodity through the most feasible certification system such as the Good Agricultural Practices (GAP) or organic certification.

Since Quinoa is not a native crop of Bhutan it did not have a local name. The Ministry of Agriculture and Livestock (MoAL) has given Bhutanese names to quinoa in different local languages (Table 1.) In Bhutan the wild relative of Quinoa, Chenopodium album is found abundantly as a weed in the cultivated drylands.

Table 1: Local names of Quinoa

No	Language	Name
1	English	Royal Quinoa
2	Dzongkha	Ashi Heychum
3	Sharchop	Ashi Mo
4	Lhotsham	Rani Bethu

QUINOA BACKGROUND

Quinoa was first introduced to Bhutan from Peru in 2015 by the Department of Agriculture (DoA) with support from the FAO [3]. Since then, it has been successfully cultivated from as low as 150 m asl in Samtenling, Sarpang, to as high as 3,500 m asl in Phajoding, Thimphu. Drawing on field-level experiences and research, the crop was gradually promoted across all 20 dzongkhags. However, as a new crop, domestic consumption remained low, production levels were insufficient for export, and farmers faced challenges such as germination issues and limited technical knowledge on production.

In 2021, quinoa was identified as Bhutan's One Country One Priority Product (OCOP) and prioritized in the 13th Five Year Plan (FYP). Under the OCOP initiative, the Flexible Voluntary Contribution (FVC) project supported the intensification of quinoa production nationwide. Quinoa was also incorporated into the Ministry of Finance's Price Guarantee Scheme (PGS), ensuring marketing support through fixed prices and aggregation by FMCL. Promotion efforts were concentrated in 14 dzongkhags identified through crop suitability mapping, alongside research on new germplasm for varietal development and initiatives to increase consumption among farmers and institutions. Awareness is gradually expanding, and market opportunities are improving for Quinoa in Bhutan.

BOTANY AND PHYSIOLOGY

Quinoa is a dicotyledonous annual plant belonging to the family Amaranthaceae [4]. It is an annual herbaceous plant with a thick, erect, woody stalk and taproot system. The plant height can vary from 0.3 to 3 meters depending on environmental conditions and produces different colours of seed namely white, yellow, and pink, to darker red, purple, and black [5]. Quinoa is a facultative short-day and day-neutral plant [6]. This nature allows quinoa to flower and set seed under various day lengths, including short-day and long-day conditions. However, quinoa also shows sensitivity to day length. Although it can flower under longday length, the process of flowering may be delayed or affected as compared to short-day conditions. When the day length is longer, plant height and biomass increase significantly, but this could delay maturity and reduce grain yield. This is very common in the high and mid altitude production zones of Bhutan when quinoa is sown from April to July. Day length of 18 hours and above causes late maturity in quinoa, showing a strong photo period sensitivity [7]. Quinoa is predominantly self-pollinated, but cross-pollination can occur up to 10 to 15%. Seed is produced in large clusters on a panicle. Quinoa is a tetraploid with four sets of chromosomes (2n = 4X = 36 chromosomes) [8] and has distinct morphological characteristics, which can also be influenced by genetic X environment interaction. The different parts of the quinoa plant are shown in figure 1.

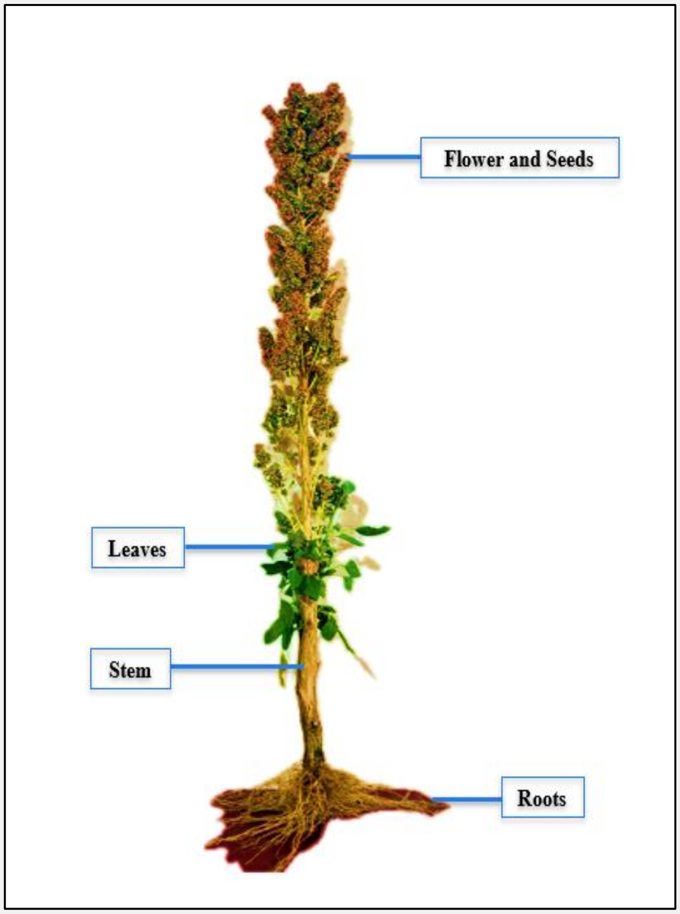

Figure 1: Parts of Quinoa plant

Figure 2: Different growth stages of quinoa

TYPES OF QUINOA CROP

Quinoa is generally categorized into five groups or eco-types [9].

I. Quinoa from the inter-Andean valleys which grows in areas between 2300 and 3500 m asl, receiving annual rainfall between 700 and 1500 mm.

II. Quinoa from highlands (also called Altiplano of the Andes) grows between 3500 and 3900 m receiving annual rainfall of 400–800 mm.

III. Quinoa from the edges of deserts and high-altitude salt lakes (Salares) which grows in areas nearly 4000 m asl receiving annual rainfall of 150–300 mm and with many days of frost.

IV. Quinoa found at sea level (Coastal) adapted to the regions lying between sea level and 1000 m asl and receiving annual rainfall of 500 to 1500 mm.

V. Quinoa from the Yungas grows under tropical moisture conditions and in areas with high levels of precipitation.

NUTRITION PROFILE

The ancient Inca Civilization of South America considered quinoa as a sacred food and referred to it as the "mother grain" in their language. Quinoa, high in protein and one of the few plant foods that contain all nine essential amino acids, is gluten-free and has a low Glycemic Index (GI) of 53, which makes it a suitable diabetic food. The nutrient profiling of Bhutanese quinoa by Mahidhol University, Thailand, has established that 100 grams of quinoa contains 372.78 kcal of energy, 13.05 g protein, 5.53 g total fat, 67.72 g carbohydrate, and 7.31g dietary fiber (Table 2). Other nutrients and mineral contents are also presented in (Table 3).

Table 2: Nutrient Profile of Bhutanese quinoa

Nutrients	Energy (kcal)	Moisture (g)	Protein (N*6.25) (g)	Total fat (g)	Total carbohydrate (g)	Total Dietary fiber (g)	Soluble dietary fiber (g)	Insoluble dietary fiber (g)
Values per 100 gms	372.78	10.08	13.05	5.53	67.72	7.31	3.98	3.33
Nutrients	Ash (g)	Calcium (mg)	Magnesium (mg)	Sodium (mg)	Potassium (mg)	Iron (mg)	Copper (mg)	Zinc (mg)
Values per 100 gms	3.63	52.88	179.43	7.89	1012.09	4.2	0.62	3.54
Nutrients	Chloride (mg)	β-carotene (μg)	Vitamin B1 (mg)	Vitamin B2 (mg)	Vitamin C (mg)	Vitamin E (mg α-tocopherol)	Folate (μg DFE)	Vitamin B12 (μg)
Values per 100 gms	44.28	10.31	0.38	0.03	Not Detected	4.172	239.8	0.25

Table 3: Comparison of macro nutrients of quinoa (Bhutan sample) with main cereals, meat, and dairy products

Macro Nutrient (per 100 gms)	Quinoa (Bhutan)	Rice	Maize /Corn	Wheat	Soybeans	Meat (Poultry)	Egg	Milk
Energy (Kcal)	372.78	354	111	354	345	127	159	68
Protein (g)	13.05	6.8	3.4	11.6	34.6	22.7	13	3.5
Fats (g)	5.33	0.7	1.4	1.3	17.8	4	11	4.1
Carbohydrate (g)	67.72	79.7	21.1	73.7	11.6	0	1.3	4.2

Source: Mahidhol University for quinoa (Bhutan) and The Concise ASEAN Food Composition Tables for other cereals

PRODUCTION SYSTEMS

Despite its small geographical size, Bhutan possesses a diverse agro-ecosystem and climate which is largely influenced by the mountains. Quinoa has been evaluated and successfully adapted under different Agro-ecological Zones (AEZ), landuse and crop production systems in the country. Quinoa has been successfully harvested from 100 m asl upto 3500 m asl in Bhutan. Based on actual field validations, three distinct production zones, namely high, mid, and low, are recommended for quinoa production. Each production AEZ and production zone has specific challenges. Generally, quinoa is very sensitive to frost damage at the seedling and flowering stage, and temperature above 35ºC affects flowering and seed setting.

In high-altitude areas (1800–3000 m asl), poor seed germination, frost during germination (if sown before mid-April) and flowering (in late-sown crops), along with risks of pre-harvest sprouting (PHS) and leaf miner infestation are the main issues. Mid-altitude zones (1200–1800 m asl) face similar germination issues, with erratic monsoon patterns causing moisture stress affecting crop establishment. Additional challenges include PHS, temperatures exceeding 35°C during flowering, leaf miner incidence, and generally low productivity. In low-altitude regions (100–1200 m asl), quinoa is grown during the winter season, and the moisture stress and shorter day lengths hinder crop performance.

The production zones, elevation range, agro-ecosystem and dominant land use and crop production systems recommended for quinoa are described in Table 4.

Table 4: Production zones, elevation range, agro-ecosystem, and dominant production system for quinoa cultivation in Bhutan

Production Zone	Elevation Range	Agro-Ecosystem	Land Use and Crop Production System
High Altitude	(1800-2700 m asl)	Warm Temperate	Dryland (Potato Based)
Mid Altitude	(1200-1800 m asl)	Dry Subtropical Transitional Zone	Dryland (Maize and Potato Based)
Low Altitude	(600-1200 m asl)	Dry subtropical, Humid Subtropical	Dryland &Wetland (Potato, maize and rice based)
	(100-600 m asl)	Wet Subtropical	Dryland & Wetland (Maize and rice based)

QUINOA SUITABILITY IN BHUTAN

The crop suitability map for quinoa in Bhutan is developed using the five most relevant parameters which are elevation range, temperature, rainfall, soil pH and slope (Figure 3). The weightage assigned for elevation is 50% as it is the key determining parameter (affects the climatic conditions during growing season) for successful quinoa cultivation in a mountainous terrain. The weightage allotted for temperature is 25% (affects seedling mortality, flowering and grain setting) and rainfall is 15%, soil pH and slope 5% each (Table 5).

Table 5: Parameters and allotted weightage for developing a quinoa suitability map

Parameters	Highly Suitable	Moderately Suitable	Unsuitable	Weightage (%)
Soil pH	6-8	5-6	>8.5, or < 5	5
Mean Temperature (°C)	15-20	20-35 or 0-15	high >35 or < 0	25
Annual Precipitation (mm)	1000-1500	500-999	<200	15
Elevation (masl)	600-1800	1800-3000 or 300-600	>3000 or <300	50
Slope (%)	0-20	21-45	>45	5

The quinoa suitability map indicates the eastern, southern, and central Dzongkhags (green and yellow) as highly suitable or moderately suitable for quinoa (Figure 3). The high-altitude northern Dzongkhags (gray) are mostly unsuitable, most likely due to elevation and temperature. The suitability map also confirms the field validation data obtained through trials and demonstrations.

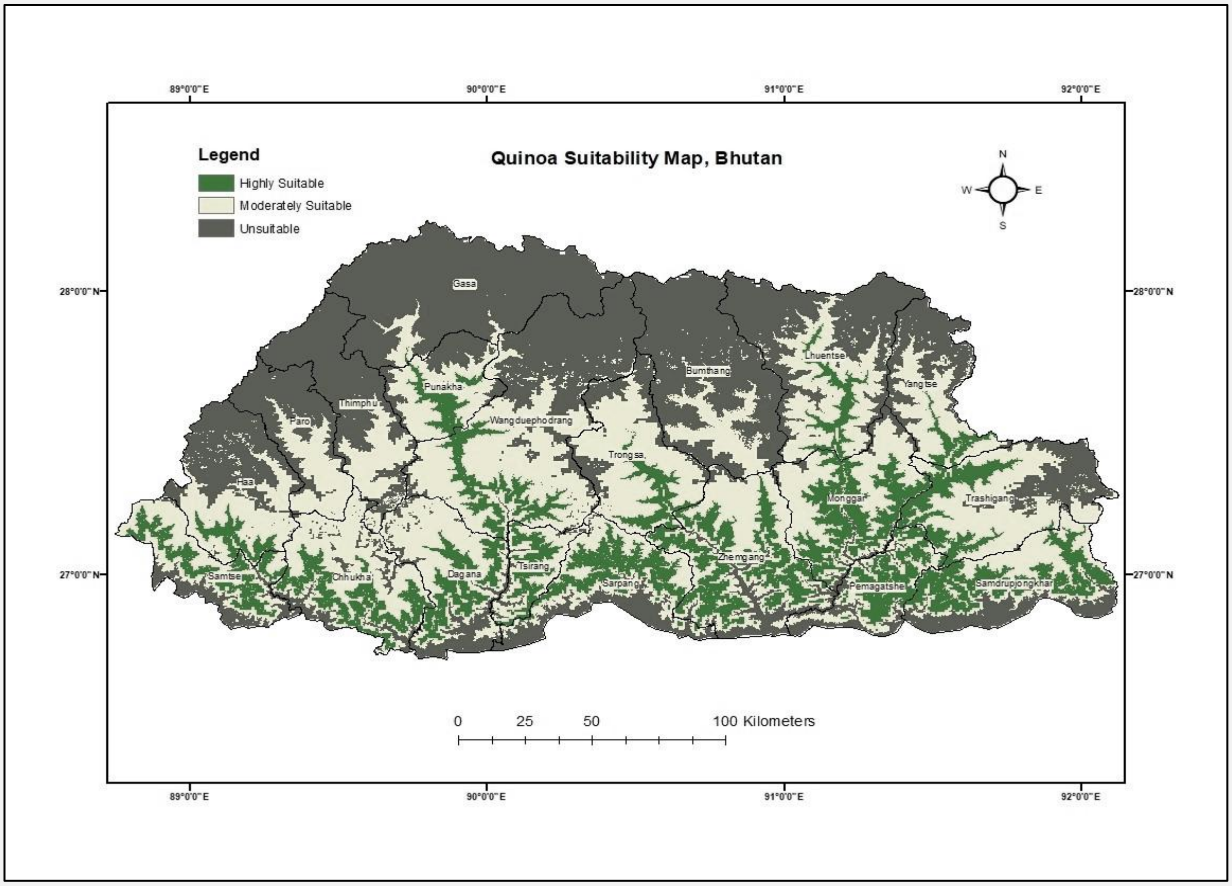

Figure 3: Quinoa suitability in Bhutan

CROPPING PATTERN

Through adaptive trials undertaken by the regional ARDCs, different cropping sequences were evaluated with the aim of fitting quinoa into the farmers' traditional cropping systems. The recommended cropping patterns or sequence for the different production zones are presented in Table 6.

Table 6: Recommended cropping patterns/sequence for quinoa

Production Zone	Production System	Traditional Cropping Pattern	Recommended Cropping Pattern	Main/Second Crop
High Altitude	Dryland	Potato-fallow Potato-turnip Potato-winter wheat Potato-mustard Potato-vegetables Buckwheat-fallow Vegetables-vegetables	Quinoa-fallow Quinoa-winter wheat /barley Buckwheat–quinoa (early) Vegetables-quinoa Quinoa-peas/turnip	Main and second crop
Mid Altitude	Dryland	Potato-mustard Maize-barley Maize-vegetables Maize-mustard	Potato-quinoa Maize-quinoa Potato + Maize-quinoa Vegetables-quinoa	Second crop

		Chilli-vegetables		
Low Altitude	Dryland	Potato-vegetables Maize-mustard Maize-maize Peanut-fallow Maize -millet Millet-millet	Maize-quinoa Peanuts-quinoa Millet-quinoa	Second crop
	Wetland	Rice-vegetables Rice-fallow Rice-wheat	Rice-quinoa (avoid waterlogged areas)	Second crop

SOIL AND CLIMATE

Climate: Quinoa is a versatile crop and has been adapted to different types of agroecosystems from its center of origin. Studies have established that quinoa can be cultivated in an environment with a humidity range of 40 to 90%. It can be grown at altitudes varying from sea level to 4500 m asl, and it also can tolerate temperature variation from -8°C to 38°C. It can adapt under desert, warm and dry, cold and dry, temperate and rainy, temperate with high relative humidity, and high mountain areas. There are varieties or ecotypes adapted to each climate. In Bhutan, it has been successfully harvested in the altitude range of 300 to 3000 m asl, covering wet subtropical to cool alpine AEZ. Quinoa is susceptible to frost damage in the early growth stage, and there will be no grain formation when the temperature is above 35°C during the reproductive phase. Seed germination is also hampered when sown during high temperature conditions.

Soil: Generally, quinoa establishes very well under marginal environments with low soil fertility. It prefers well-drained, sandy loam to loamy sandy soils with a slightly acidic to neutral pH [10]. It does not tolerate waterlogging and excess humidity. Quinoa requires soils with good drainage and high organic matter, with moderate slopes and average nutrient content. The suitable soil pH range for quinoa is 4.5 to 9. The National Soil Services Center (NSSC) has conducted soil analysis and fertilizer trials under different production systems and has established that soil pH in the Bhutanese soil is within the acceptable range for quinoa. The soil analysis revealed that in the root layer zone (0-20 cm), the average pH was 6. The overall pH ranges from 5.4-6.5, which is acceptable for quinoa.

Temperature: The optimum temperature range for quinoa growth is 15-20ºC. However, quinoa can grow in the temperature range of 10-25 ºC [11]. Quinoa can withstand extreme temperatures ranging from -8ºC to 38ºC. However, high temperatures above 35ºC cause flower abortion, pollen sterility, and no grain setting.

Rainfall: Quinoa is a drought-tolerant crop and produces acceptable yields with rainfall of 100 to 200 mm. The most critical stages of moisture requirement in quinoa are seed germination, crop establishment, flowering and grain filling. Quinoa as a winter season crops at lower elevation, irrigation during critical stages will enhance productivity. The water requirement of quinoa is estimated at 300-400 mm, but production can be higher if water is available up to 866 mm [12].

VARIETIES

The NCQP based at ARDC Wengkhar is evaluating new quinoa accessions and selecting suitable lines for different quinoa production zones. New germplasm from China, Pakistan and the International Center for Biosaline Agriculture (ICBA) are undergoing evaluation. The performance of new varieties will be evaluated through multi-location Nationally Coordinated Trials (NCT) across different AEZs and production zones. The best performing accession will be recommended for release to the Variety Release Committee (VRC) of the DoA. Currently, four varieties are recommended for cultivation in Bhutan (Table 7). The variety Ashi Heychum-AM (Amarilla Marangani) is recommended for all three quinoa production zones. However, the sowing time is different and specific for each production zone.

Table 7: Information on released varieties

Variety	Bhutanese Name	Origin	Plant Height (cm)	Maturity (Days)	Grain Colour	Potential Yield (kg/acre)
Amarilla Marangani	Ashi Heychum- AM	Peru	188	173	Yellow	750
Amarilla Saccaca	Ashi Heychum- AS	Peru	165	170	Yellow	900
Ivory 123	Ashi Heychum- 123	India	122	150	Brownish	900
DoA-1-PMB-2015	Ashi Heychum- TW	NA	120	140	Brownish	750

Figure 4: Quinoa grains images

SEED AND SEED RATE

Quinoa seeds are very small in size and highly sensitive to moisture, temperature and humidity. It loses viability very fast, resulting in poor seed germination as compared to other cereals due to integument porosity [6]. It is very important to do the germination test to confirm seed viability prior to sowing the crop. Farmers can save their own seed by drying it adequately to bring the moisture content (MC) between 8 to 10%. The dried seeds must then be stored in airtight containers under low humidity. Super grain bags promoted by the National Plant Protection Center (NPPC) are best for storing quinoa seeds. Small quantities can be stored in airtight containers in the refrigerator. The general recommended seed rate for quinoa is 2.5 to 3 Kg/acre. A higher seed rate should be used to get a good crop stand, which can be maintained later through thinning.

SOWING TIME

Quinoa can be successfully cultivated in Bhutan across the six different AEZs. However, the time of sowing is very critical for a successful harvest. Sowing time depends on the specific location, and the general recommendations are made in Table 8.

Table 8: General sowing time for different quinoa production zones

Production Zone	Land Use System	Main Cropping Systems	Recommended Sowing Time
High Altitude	Dryland	Potato based	Mid-April to May Sowing should be done after the occurrence of the last frost
Mid Altitude	Dryland	Potato & Maize-based	Mid July – Mid August For transitional zones between dry and humid subtropical to warm temperate – Mid August to first week of October.
Low Altitude	Dryland	Maize based	Mid-October – Mid-November
	Wetland	Rice based	Mid-November to the First Week of December

FIELD PREPARATION

The field preparation (Figure 5) methods for Quinoa are very similar to those for mustard and wheat. When a power tiller is used, first ploughing followed by soil pulverization with a rotavator is sufficient. When bullocks are used, first ploughing followed by a second ploughing and then leveling with a locally made leveler is very important to prepare a good seedbed. Since Quinoa seeds are very small in size, soil clods should be thoroughly broken to make the soil fine for good seed germination. Quinoa requires a leveled field, well-drained seedbed to avoid waterlogging.

Quinoa does not require the preparation of raised beds like that for vegetables and making ridges like for potatoes.

SOWING METHOD

Figure 6: Sowing of quinoa

Quinoa can be sown in line and broadcast like mustard; however, line sowing is recommended for easy weed control and other intercultural operations like earthing up and thinning. The recommended spacing between the rows is 50-60 cm, and the plant-to-plant spacing should be maintained at 10-20 cm by thinning. For line sowing, there is no need to use a rope or a string. Like in the case of potatoes, lines can be drawn approximately, keeping a line-to-line spacing of 60 cm or 2 feet between lines. The recommended plant population for optimum production is 20-25 plants per m^2 or 80,000 to 100,000 plants per acre. A shallow, broad furrow of 2-3 cm depth should be marked with a spade, and quinoa seeds should be evenly broadcast on the marked furrow. After the seed is broadcast, it should be covered by the soil with the help of a hard broom. The sowing depth is 2-3 cm. Quinoa seeds are susceptible to desiccation if exposed to direct sunlight or waterlogging. Quinoa seed may not germinate if the conditions are too dry or the seed is sown too deep. Seed germination occurs within 24 hours after planting when adequate moisture is present, and seedlings emerge in three to five days. When plants germinate and attain a height of 10-15 cm, thinning should be done to maintain a good plant population. The young plants that are thinned out can be consumed as fresh vegetables or fed to animals and poultry.

FERTILIZER RECOMMENDATION

Quinoa is mostly grown in marginal environments with minimum external inputs. Based on the fertilizer trial conducted by NSSC, the use of Farmyard Manure (FYM) and fertilizers is recommended to optimize productivity. The following recommendations are made:

I. Application of 5 Mt/acre of well-rotted FYM as soil conditioner before field preparation for all production zones and production systems.

II. Application of NPK is recommended at the rate of 30:20:20 N: P_2O_5: K Kg/acre.

III. If Suphala is used, then apply 125 Kg/acre of Suphala (16:16:16) as a basal application and 22 Kg/acre of Urea (46 % N). The entire dose of Suphala (125 Kg/acre) is applied as a basal dose during land preparation.

- Nitrogen in the form of Urea should be top-dressed in two split doses.
- The first top dressing (11 Kg/acre of Urea) should be done three weeks after sowing when the crop is at the 4-6 leaf stage. This application helps in tillering and leaf development.
- The second top dressing (11 Kg/acre of Urea) should be done at panicle initiation to support panicle development and grain filling. If using straight fertilizer like Urea (46% N), Single Superphosphate (16% P_2O_5), and Muriate of Potash (60% K) is used then:
- Apply 65 Kg/acre of Urea, 125 Kg/acre of SSP, and 33 Kg/acre of MoP.
- Apply the entire SSP, MoP, and half the urea (33 Kg/acre) as a basal application during land preparation.
- 32 Kg/acre of Urea should be split into two applications. Top dress 16 Kg/acre 3 weeks after sowing, and the second 16 Kg/acre Urea should be top dressed during panicle initiation.
- Avoid waterlogging to prevent nutrient leaching and root damage.

WEED MANAGEMENT

The National Plant Protection Center (NPPC) has recorded that the major weeds (Figure 6) in quinoa are *Galinsoga quadriradiata* (Shaggy soldier), *Galinsoga parviflora* (Gallant soldier), *Persicaria nepalensis* (Nepal knotweed), *Bidens pilosa* (Black-jack), *Ageratum conyzoides* (Billygoat weed), *Polygonum aviculare* (Common knotgrass), and *Cynodon dactylon* (Bermuda grass). The weed pressure is higher in high altitude areas where quinoa is sown in spring and grows through the summer season. In high and mid production zones, competition from weeds is greater when quinoa is planted in spring and summer, as warm temperatures and monsoon rain during the growing period favor fast weed growth.

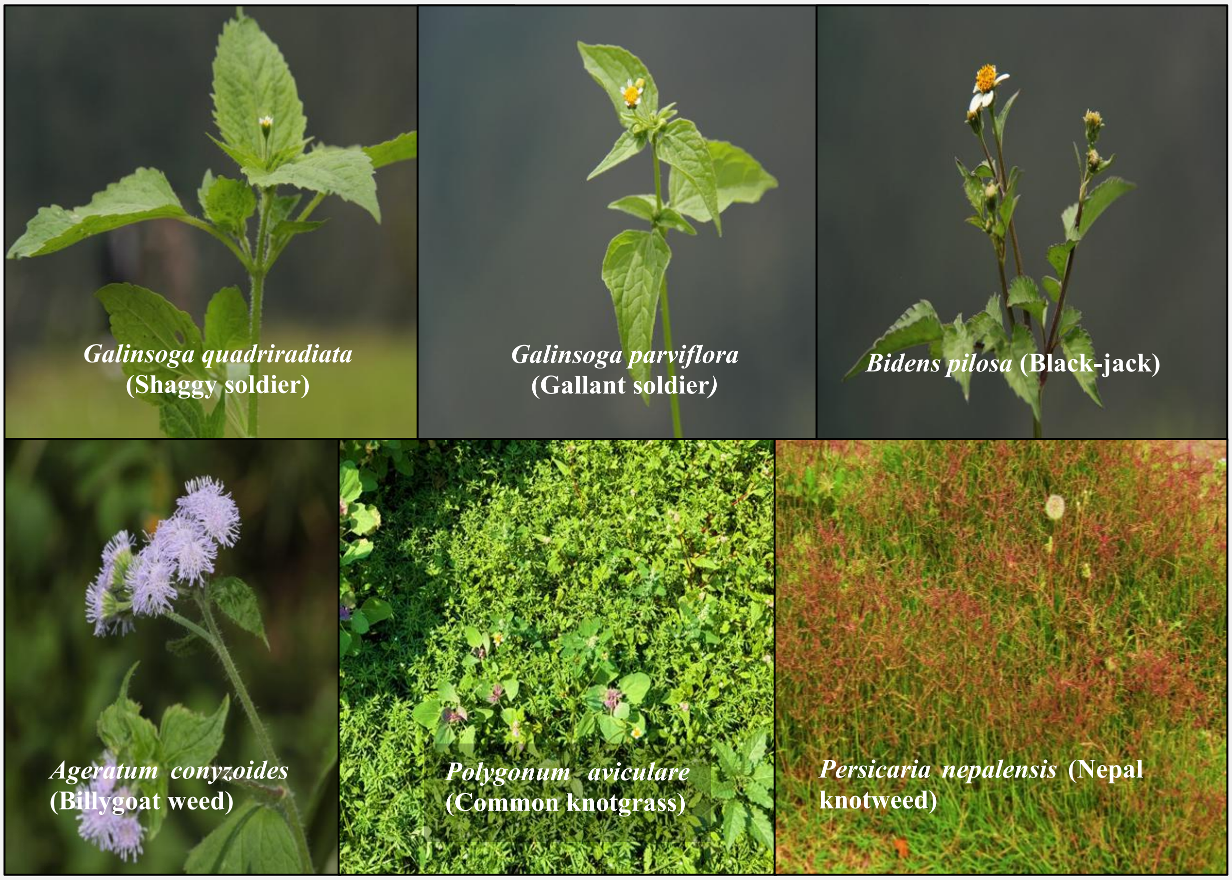

Figure 7: Weeds in quinoa crop

Effective management of weed pressure in the early growth stage of quinoa is a very critical operation for a successful harvest. Weed control in quinoa fields is difficult since plants grow slowly during the first two weeks after emergence. Two to three hand weddings will be necessary for good crop growth and weed management (Figure 8). Sowing seeds in line makes hand weeding easy and facilitates the use of hand tools and mechanical weeders. During the weeding operations, the soil in between the furrows should be loosened with a spade for good weed control and the growth of the crop.

Figure 8: Hand weeding and thinning, and the use of a weeder in quinoa

PESTS AND DISEASES

The quinoa crop is only about a decade old in Bhutan, and there is very limited information on pests and diseases affecting this crop. Identifying economically important pests and diseases is essential for developing Integrated Pest Management (IPM) strategies to support sustainable production. The NPPC has undertaken a national survey to document the pests and diseases of the quinoa crop in Bhutan. The survey covered different Dzongkhags, various altitudes, production systems, and crop stages. The NPPC has identified four major insect pests that are of economic importance on quinoa in Bhutan. Apart from sporadic occurrences of Downy Mildew, no major diseases were observed or reported by farmers.

Figure 9: Leaf miner damages

Leaf Miner (*Liriomyza* sp.) (Diptera: Agromyzidae): Leaf Miner is a tiny black fly, about 1.7 to 2.3 mm long, with yellow spots on the thorax. The popular hosts for Leaf miner are quinoa, potato, tomato, cabbage, cauliflower, broccoli, bean, pea, spinach, onion, lettuce, maize, melon, and cucumber. The larvae feed on leaves, causing a characteristic serpentine mine which is white to pale green, finally creating black or dried brown areas (Figure 9). As the larvae feed between the upper and lower leaf surfaces, the width of mines increases, disrupting photosynthesis. Adult females also cause damage by puncturing the leaf surface with their ovipositor during feeding and egg-laying, resulting in numerous small white or yellowish spots. The damage to leaves weakens the plants, reduces growth, delays development, and leads to significant yield loss.

Control Measures:

Non-chemical management

- Remove and destroy infested leaves and plant debris to reduce populations.
- Practice crop rotation to break the pests' life cycles.
- Control weeds around crops, as they can host leaf miners.
- Under organic management, a weekly spray of Neem oil 10,000 PPM (3-5 ml per liter of water) has been found effective against larvae.

Chemical management

- Use contact insecticides like Cypermethrin 10% EC (1 ml per liter of water) and Malathion 50% EC (2 ml per liter of water), which mainly kill adult flies. These insecticides are not effective against larvae inside the leaves.
- To control larvae, use systemic insecticides such as Chlorantraniliprole 18.5% SC (0.3 ml per liter of water).

Figure 10: Black Bean Aphids

Black Bean Aphids (*Aphis fabae* Scopoli) (Hemiptera: Aphididae): The black bean aphid is a small, soft-bodied insect about 2–3 mm long, usually dark brown to black with a pear-shaped body. It has long antennae and two short tube-like structures (cornicles) at the rear. The common hosts of the Black bean aphid are beans, peas, potato, cabbage, cauliflower, celery, eggplant, cucumber, cucurbits, chili, tomato, spinach, sunflower, radish, and carrot. The visible symptoms include dense clusters of small black aphids on leaf undersides and stems, sticky surfaces from honeydew, and the presence of molted skins. The aphid colonies often form dense clusters on the undersides of leaves, stems, and growing tips, where they feed by piercing plant tissues and sucking sap. Aphids damage quinoa by sucking sap from young leaves, stems, and growing points, causing stunted growth, leaf curling, yellowing, wilting, and premature leaf drop. Heavy infestations lead to distorted and deformed foliage, poor flowering, and overall reduced plant vigor and yield. Aphids also excrete honeydew, which promotes the growth of black sooty mold on leaves and stems, further reducing photosynthesis and crop quality.

Control measure:

Non-chemical management

- Eliminate alternative hosts like Chenopodium album and Sonchus near the crop.
- Use a strong jet of water to physically dislodge aphids from plants.
- Spray with oils such as horticultural mineral oil (HMO), which are less harmful to beneficial insects and effective against aphids.

Chemical management

- Use contact insecticides like Cypermethrin 10% EC (1 ml per liter of water) and Malathion 50% EC (2 ml per liter of water), which are very effective for controlling black bean aphids. Both should be applied during early infestation with good leaf coverage, especially on the undersides.

Green Peach Aphids (*Myzus persicae* Sulzer) (Hemiptera: Aphididae): Green Peach Aphids are small, soft-bodied insects, typically pale green to yellow or pink, and are visible to the naked eye. The adults have yellowish-green, pear-shaped bodies about 0.05 inches in length. The hosts are beans, cabbage, cucurbits, tomatoes, spinach, lettuce, potatoes, peaches, and various ornamental plants, including chrysanthemums, roses, and trees like Weeping Willow. The most notable damage caused by green peach aphids is through the transmission of plant viruses. Green peach aphids can attain very high densities on young plant tissue, causing water stress, wilting, and reduced growth rate of the plant. Damaging levels are

Figure 11: Green Peach Aphids

characterized by large numbers of aphids found on the underside of leaves. Extensive feeding causes plants to turn yellow and the leaves to curl downward and inward from the edges. Infested plants often turn pale and develop a sticky appearance due to the excretion of honeydew by the aphids. This sticky substance promotes the growth of sooty mold on the leaves.

Control measure:

Non-chemical management

- Predators, especially the larvae of syrphid flies and ladybird beetles, which feed on aphid eggs, are important for keeping aphid pests in check.
- Remove all weeds that serve as secondary hosts for aphids.
- Pick and destroy leaves that are heavily infested with aphids.

Chemical management

- Spray contact insecticides like Cypermethrin 10% EC (1 ml per liter of water) and Malathion 50% EC (2 ml per liter of water to control aphids on the plant surface.

***Lygus* Spp. (Hemiptera: Miridae):** Lygus bugs are small, oval-shaped insects, about 5 mm long, known for their variable coloration, ranging from pale green to reddish-brown. Adult lygus bugs are 0.2 to 0.3 inches long. They are about one-half wide and have a flattened supper side. Lygus species have a distinctive, contrastingly colored triangle in the middle of the back where the wings attach. Both adults and nymphs have piercing sucking mouth parts used to feed on plant sap, causing damage to crop. The common hosts are potato, strawberries, celery, eggplants, and tomato. Adults and nymphs use a piercing-sucking mouthpart called proboscis to feed on reproductive structures. All species of Lygus bugs feed preferentially on buds, flowers, or developing seeds. Feeding on buds, flowers, and young pods causes "blasting" (buds turn white and fail to develop), flowers fall without forming pods, or pods drop without

Figure 12: Lygus bugs

maturing. The overall result of the infestation is reduced grain quality and yield loss, particularly if infestations occur during the reproductive stages.

Control measure:

Non-chemical management

- Reduce or suppress weed host plants throughout the growing seasons to minimize Lygus populations.
- Rotate quinoa with non-host crops to disrupt Lygus life cycles and reduce buildup of populations.
- Use sweep nets for small plots to reduce adult populations during peak infestation.
- Encourage natural enemies like parasitoid wasps, spiders, and lacewings.

Chemical management

- Spray contact insecticides like Cypermethrin 10% EC (1 ml per liter of water) and Malathion 50% EC (2 ml per liter of water to control bugs.
- Apply during early morning or late evening to minimize impacts on pollinators and natural enemies

DISEASE

Figure 13: Downy mildew

Downy mildew is one of the main diseases of quinoa. It is caused by infections of the biotrophic oomycete *Peronospora variabilis* Gaüm. Unlike true fungal infections, these diseases are caused by water-loving oomycetes that thrive in cool, moist environments and spread rapidly under high humidity or prolonged leaf wetness. Once downy mildew infects a plant, it can produce new spores within 4 to 10 days, allowing the disease to spread quickly. The pathogens require a living host to survive and reproduce, as they cannot persist in dead organic matter. These organisms reproduce through sporangia, which are dispersed by wind, water splashes, or insects. The hosts for the pathogens are onion, brassica, cucurbits, lettuce, Pea, spinach, rose, snapdragons, and pansy flowers.

The pathogen infects the leaves, which often develop yellowing around angular areas, with lesions varying from green islands to dark brown or purplish patches. A key identifying feature is the downy, white, grey, or lavender fungal growth that appears mostly on the underside of the leaves. Severe infections lead to premature leaf drop, reducing the plant's photosynthetic capacity and overall vigor. The symptoms of quinoa begin as small, angular yellow spots on the upper leaf surface, which correspond to a grey to purplish fungal growth underneath. As the disease progresses, the lesions expand and may cause leaf curling, browning, and extensive defoliation.

HARVESTING

Figure 14: Harvesting Quinoa

When the crop is ready, it can be harvested manually with sickles by cutting the plants 10-15 cm above the soil and leaving the stubble on the soil. Maturity of the quinoa depends on variety and location. In the high and mid altitude quinoa production zones short duration varieties take 120 to 150 days to mature while the longer duration varieties mature in 170 to 180 days. In the low production zone, the crop matures much faster and takes 120-130 days. Quinoa is ready for harvest when its leaves turn yellow or red depending on the variety. If the leaves on the panicles have dried and the grains can be seen on the panicle, it has attained physiological maturity. Another method to judge maturity is to tap the panicle with the hands. If the grains drop on gentle tapping of the panicle then it is ready for harvest.

Rain should be avoided during harvest because mature quinoa seed will germinate within 24 hours after exposure to moisture. If harvesting is delayed and the mature grains are wetted by rain it leads to the sprouting of gains on the panicles causing Preharvest Spouting (PHS). PHS deteriorates grain quality, loss of seed viability and yield loss. Delayed harvesting can also cause quinoa grains to appear pale and discoloured, affecting the grain quality.

DRYING


Figure 15: Drying of harvested quinoa

After harvesting quinoa, it should be sundried or made into bundles and hung for drying and curing. Harvested crops can be sundried in the field like paddy. It can also be hung on the ceiling of the house like farmers practice for wheat and barley. It can also be stacked in heaps and covered by polythene sheets to avoid getting wet. Curing and drying of the crop should be done for at least 7-10 days for easy threshing.

THRESHING

Threshing operation involves the separation of the grains from the panicles. It can be done mechanically using the multi-crop threshers. The portable gasoline multi crop thresher with 7 HP (Horsepower) capacity is suitable for threshing quinoa . It can also be used to thresh other cereals like wheat, barley, millets, buckwheat and rice. The fuel used is petrol with a tank capacity is 3.5 Litres.

Threshing can also be done manually by beating the dried panicles with a stick. Dried panicles can also be trampled by feet to shred the grains. Once the grains are properly threshed, the stubble can be used as soil mulch, animal bedding, or chopped and put into the compost pit to prepare compost.

WINNOWING

Winnowing is done to separate and clean the grains from the bran and other unwanted materials. Winnowing can be done both manually using locally made winnowers and power operated winnowers.

STORAGE

The three most critical factors for safe storage of quinoa grains are moisture content (MC), temperature, and relative humidity (RH). The clean grain obtained after winnowing should be adequately dried to bring down the moisture content (MC) to 8-10% for safe storage. Quinoa seeds are hygroscopic and readily absorb moisture from the atmosphere. The grains should be properly dried without being exposed to direct sunlight to maintain the product quality. Grains should be stored in a clean and dry environment. For seeds, the dried grains should be stored in airtight, hermetic grain bags (super grain bags) promoted by NPPC (Figure: photo of super grain bag used for storage).

For consumption, the dried grains can be stored in polypropylene bags or plastic bins in cool and dry places. The filled grain bags should be stacked properly on wooden planks. The best storage conditions for quinoa that help preserve the nutrients, seed viability for the next growing season, and grain quality have been reported to be temperature of 4°C and below, seed MC of less than 12% and the use of hermetic grain bags [13]. The ideal RH should not exceed 50-60%.

MILLING

Figure 16: ZLN-4 Rice Mill modified for milling Quinoa to remove saponin.

Milling or dehusking is the last step before the quinoa grains are ready for cooking. Milling in quinoa helps to remove saponin. Quinoa grain contains saponin, which is a naturally occurring compound concentrated in the outer layer of the quinoa seeds. Saponin is a naturally occurring toxic compound that is found in quinoa seeds [6]. Saponin is bitter in taste and has harmful effects, and must be eliminated before the consumption of quinoa [14]. Quinoa milling involves the separation of the episperm, which is a thin layer that encases the entire quinoa seed and contains maximum saponin. It is also important to maintain MC of 12% to obtain optimum quinoa grains after milling.

Quinoa milling is done mechanically using the dry or wet milling process. For household scale, dry milling with the ZLN-4 Rice Mill modified for milling Quinoa. It is a compact, user-friendly machine and ideal for household use. It is electrically powered and requires a 1.5 kW single-phase motor. The milling recovery with this machine is 75-80%. Dry milling does not remove 100% saponin, and hence the milled quinoa must be thoroughly washed before preparation of dishes.

TESTS FOR SAPONIN

Figure 17: Foam test/ afrosimetric method to quantify saponin in quinoa grain

(Source: Dr. Irfan Afzal, FAO Pakistan)

The saponin content of quinoa grain can be measured using the foam test. A standard Afrosimetric method [15] is recommended to test the saponin. The stepwise process is:

1. First, weigh 0.50 g of quinoa seeds and pour into a test tube (size 160x16 mm)
2. Add 5mL of distilled water into the test tube with quinoa seeds.
3. Shake the test tube vigorously for 30 seconds in up and down movements.
4. Allow the test tube to rest for 30 minutes in a test tube stand.
5. Repeat the shaking process at least 3 times.
6. After the second rest period, shake the test tube again for 30 seconds.
7. After the final shake, rest the test tube for 5 minutes.
8. Measure the height of the foam in the test tube with a scale.
9. Foam height of less than 1.0 cm indicates saponin is absent or low; foam height of 1.0 cm to 5.0 cm indicates medium saponin; and foam height of 5.0 cm or more indicates high saponin content.

YIELD

In Bhutan, we have recorded experimental yields of Quinoa ranging from 750 to 1100 Kgs/acre. In the farmers field, grain yield ranges from 300 to 800 Kgs/acre. A high yield of 700-800 Kg/acre is recorded in the high and mid altitude quinoa production zones. In the low altitude zone, the yield varies from 300-400 Kgs/acre as quinoa is grown during the winter season, where the day length is short and crops are grown under moisture stress without irrigation. Production can be enhanced in all three production zones with the application of fertilizers, maintaining optimum plant density, and provision of supplementary irrigation at critical stages.

SEED PRODUCTION

Figure 18: Rouging off type plants from seed production plot at NCOA, Yusipang.

Quinoa seed production should follow standard production practices. Quinoa is predominantly autogamous or self-pollinated. It is also a partially allogamous or cross-pollinated species with 10-15% cross-pollination. Cross-pollination or natural hybridization can vary from 10 to 17 % [16]. The Quinoa plant has a hermaphrodite flower or bisexual perfect flower with both male (stamens) and female (pistil) in the same flower. The seed production of quinoa requires experience, art, and skills. Depending on the type of seed to be produced, the isolation requirements of quinoa are 20 m for breeder and foundation seed and 10 m for certified seed [17]. Like any other crops, monitoring and rouging off-types is very important. For all categories of seed, the minimum germination should be 85% and the seed MC 10%.

UTILIZATION OF QUINOA

Figure 19: Tender shoots and leaves of Quinoa consumed as vegetables

The parts of quinoa that can be consumed are tender leaves, shoots, and grains. Tender shoots and leaves are used as vegetables as presented in figure 19.

The milled grains free of saponin are prepared into diverse types of dishes. (input figure of milled Quinoa) It can be cooked like rice, mixed with rice or maize grits (*Kharang*), made into flour to be used in breads, noodles, and porridge. Processed grains are popularly used in salads. Traditionally, quinoa grain is roasted and then made into flour to make different types of breads, added to soups, used as a cereal, and made into pasta.

In Bhutan, efforts are made to integrate quinoa into the Bhutanese traditional menu. The simplest way to eat quinoa is to mix it with rice in the desired ratio. Rice mixed with quinoa in the ratio of 80:20 is recommended. The mixture can be cooked normally in the rice cooker. Normally, the water required for cooking quinoa is slightly less than that required for cooking rice alone. Quinoa can also be mixed with rice to prepare porridge (Thuep). Other local dishes that are recommended are quinoa kheer, quinoa dresi, quinoa fried rice, and quinoa pancake. The ingredients for different Bhutanese dishes that can be prepared by integrating quinoa are described in Table. The Department of Agricultural Marketing and Co-operatives (DAMC) has developed different menus on quinoa.

Table 9: Some traditional Bhutanese dishes integrating quinoa

No	Name of Dish	Ingredients
1	Rice + Quinoa	Rice- 1 Kg +Quinoa-200 g
2	Kharang (Maize grits) +Quinoa	Kharang- 1 Kg +Quinoa-200 g
3	Rice + Quinoa Fried Rice	Rice 500 g + Quinoa 500 g cook together and fry with other ingredients used in fried rice
4	Rice + Quinoa Thuep (Porridge)	Rice 500 g + Quinoa 500gm cook together and add other ingredients used in Thuep with Cheese/Paneer
5	Rice + Quinoa Dresi	Rice 500 g + Quinoa 500 g cook together and add other ingredients used in dresi.

Figure 20: Dishes prepared from Quinoa

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