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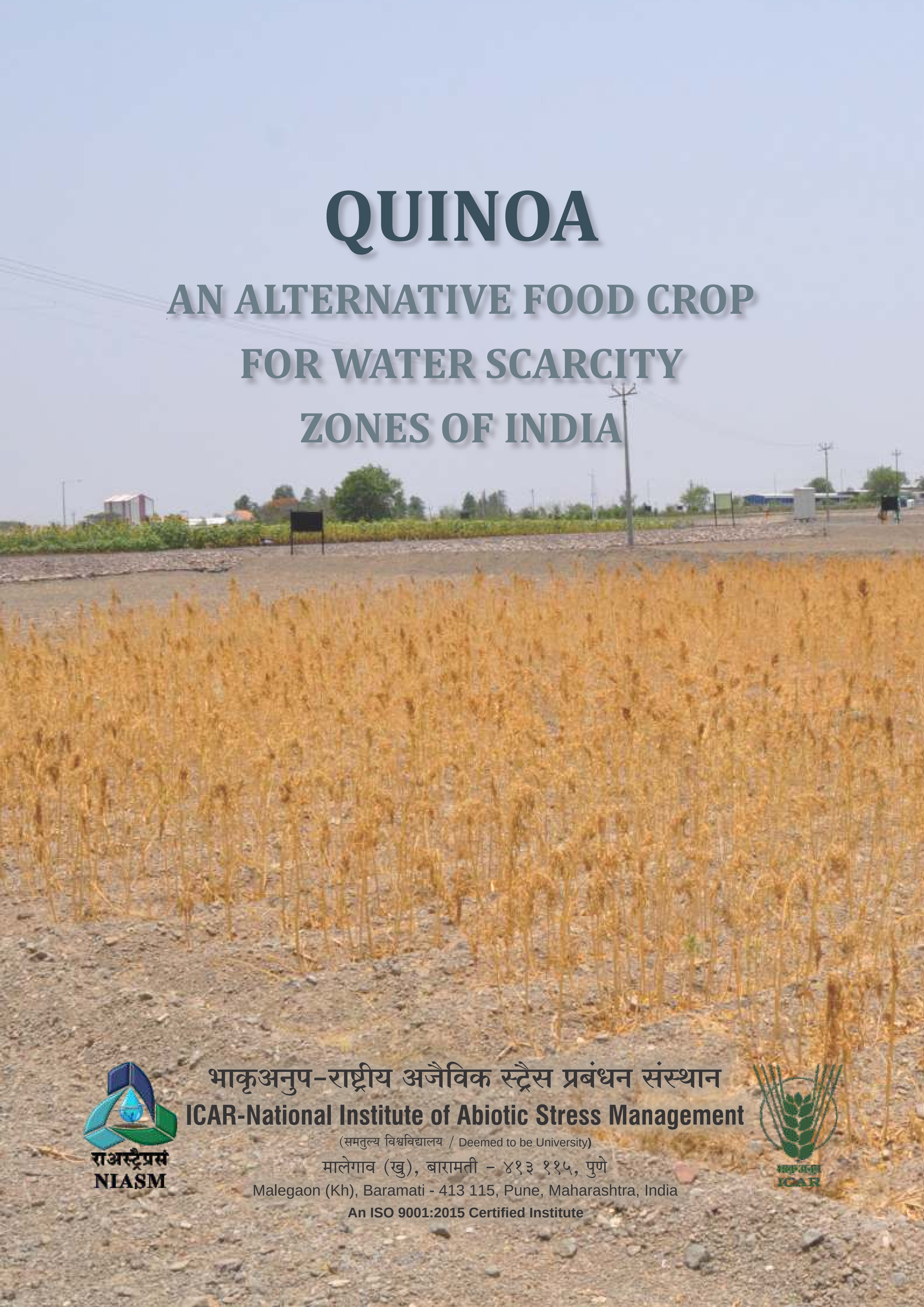

QUINOA

AN ALTERNATIVE FOOD CROP FOR WATER SCARCITY ZONES OF INDIA

भाकृअनुप-राष्ट्रीय अजैविक स्ट्रैस प्रबंधन संस्थान

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PREFACE

Climate change is expected to increase extreme events of drought and flooding due to the changes in the distribution of rainfall patterns. These extreme events are more harmful to ecosystems than changes in the annual mean precipitation. Furthermore, a rise in temperature is estimated; therefore, higher rates of water evaporation will occur, expanding even more drought areas as well as salinization of crop soils. As water availability is the most important factor in the development of plants, therefore under drought- and salt afected soils, plants super water scarcity, leading to decreases in crop productivity. In addition, increasing population in the country will require an increase in agricultural production to cope with growing food demand. Since there is no further scope of increasing the total agricultural area, the research community is trying to explore varieties or species that are more tolerant to water limitation or salinity to maintain or increase agricultural production.

Quinoa (*Chenopodium quinoa*), a native of Latin America, has high nutritional value and adaptable to extreme weather, climate and soil conditions which made Food and Agricultural Organization to declare it a crop for food and nutritional security. Further the demand for the crop has reached its peak globally in recent years. Hence, to enhance the benefit from agriculture for the farmers in water scarcity zones of Maharashtra, the suitability of the crop in the region was evaluated for two years i.e. (2017-18) & (2018-19) at ICAR-NIASM campus. The available information on crop production technology and management strategies along with its use, benefits and market potential has been compiled here for greater outreach. This will be helpful for farmers to grow a crop in water scarcity areas and marginal soils providing a good return where no other crop can be grown. Also due to less or no incidence of disease and pest during the crop growth period, it can also be grown organically at the region.

We sincerely hope that the information contained in this document will be useful for crop researchers, farmers and other stakeholders.

June, 2019 **Authors**

Introduction

Water scarcity is a major constraint for agricultural production in arid and semi-arid regions of India. Additionally, climate change is expected to increase extreme events of drought in these regions due to the changes in the distribution of rainfall patterns. Dry land Agriculture plays a distinct role in India occupying 60% of cultivated area and supports 40% of human population and 60 % livestock population. By the end of the 20th century the contribution of dry lands will have to be 60 per cent if India is to provide adequate food to 1000 million people. Therefore there is need to increase our knowledge and promote the crops that have the potential for increased production under adverse climatic conditions and Quinoa *(Chenopodium quinoa)* is one such crop that has been selected by Food and Agriculture Organization (FAO) as one of the crops destined to offer food security in the next century.

Importance

Quinoa, a pesudocereal of Chenopodiaceae family originally from the Andean mountains of South America, is adaptable to different types of soil and climatic conditions. The genetic variability of quinoa is huge, with cultivars of quinoa being adapted to growth from sea level to 4000 meters above sea level, from 40°S to 2°N latitude, and from cold, highland climate to subtropical conditions. This makes it possible to select, adapt, and breed cultivars for a wide range of environmental conditions. In addition to its tolerance to abiotic stresses, its composition is gaining international attention because of its high nutritional value (Table 1), being rich in proteins, lipids, fibers, vitamins, and minerals, with an extraordinary balance of essential amino acids. All the nine amino acids that are strictly essential for humans are present in quinoa (Table 2).It is also gluten-free, a characteristic that enables its use by celiac patients. Quinoa has a significant, worldwide potential as a new cultivated crop species and in developing countries like India, it is a crop having ability to provide highly nutritious food under dry conditions.

Table 1. Comparisons of the nutritional quality (% dry weight) of quinoa with various grains.

Crop	% dry weight					
	Water	Crude Protein	Fat	Carboydrates	Fiber	Ash
Quinoa	12.6	13.8	5.0	59.7	4.1	3.4
Barley	9.0	14.7	1.1	68	2.0	5.5
Buckwheat	10.7	18.5	4.9	43.5	18.2	4.2
Corn	13.5	8.7	3.9	70.9	1.7	1.2
Pearlmillet	11.0	11.9	4.0	68.6	2.0	2.0
Oat	13.5	11.1	4.6	57.6	0.3	2.9
Rice	11.0	7.3	0.4	80.4	0.4	0.5
Rye	13.5	11.5	1.2	69.6	2.6	1.5
Wheat	10.9	13.0	1.6	70.0	2.7	1.8

Source for quinoa : Cardoza, A. and M. Tapia. 1979. Valor nutrivia. In: Quinoa y Kaniwa. M. Tapia (ed.), Serie Libros y Materiales Educativos No. 49. Reported by J. Risi and H. W. Galwey. 1994. Analyses of the remaining crops reported by: Crampton, E. W.and L.E. Harris. 1969. Applied Animal Nutrition, 2nd ed., W. H. Freeman and Co., San Francisco.

Table 2. Essential amino acid pattern of quinoa compared to wheat, soy, skim milk, and the FAO reference pattern (1973) for evaluating proteins.

Amino Acid	Amino Acid Content (g/100g protein)				
	Quinoa	Wheat	Soy	Skim Milk	FAO
Isoleucine	4.0	3.8	4.7	5.6	4.0
Leucine	6.8	6.6	7.0	9.8	7.0
Lysine	5.1	2.5	6.3	8.2	5.5
Phenylalanine	4.6	4.5	4.6	4.8	-
Tyrosine	3.8	3.0	3.6	5.0	-
Cysteine	2.4	2.2	1.4	0.9	-
Methionine	2.2	1.7	1.4	2.6	-
Threonine	3.7	2.9	3.9	4.6	4.0
Tryptophan	1.2	1.3	1.2	1.3	1.0
Valine	4.8	4.7	4.9	6.9	5.0

Source : Johnson, R. and R. Aguilera. 1980. Processing Varieties of Oilseeds (Lupine and Quinoa), In: Report to Natural Fibers and Foods Commission of Texas, 1978-1980 (Reported by D. Cusack, 1984, The Ecologist 14:21-31).

Natural taste

In their natural taste, the seeds have a coating of bitter-tasting saponins, making them unpalatable. Most of the grains to be sold commercially are processed to remove this coating. This bitterness has beneficial effects during cultivation, as it is unpopular with birds and therefore requires minimal protection.

Uses

- Whole grain, uncooked or roasted flour, small leaves, meal and instant powder can be prepared in a number of ways.
- Several recipes such as sauce, leaf salad, pickles, soups, pastries, sweets and deserts, beverages, breads, biscuits and pan cakes which contains 15-20 percent quinoa flour can be prepared.
- It has a notably short germination period i.e. only 2-4 hours in water is enough to make it sprout. This process softens the seeds, making them suitable for salads and other foods.
- The whole plant is used as green fodder. Harvest residues are also used to feed cattle, sheep, pigs, horses and poultry.
- The leaves, stem and grain have medicinal uses. They have anti-inflammation property and also used against toothache and also as disinfection of the urinary tract.

  It is also used in the case of fractures and internal hemorrhaging and as an insect repellent.
- Saponins can be used for liquid soap, jewellery polish, detergent, eczema/dermatitis cure, pesticide/insecticide, pet shampoo, human shampoo, surf spreader/sticker, antimicrobe, parasite remover (tick, flea) etc.

Morphological characteristics

Vegetative growth

Plants grow from 1 1/2 to 6 1/2 ft in height, and come in a range of colors that vary from white, yellow, and pink, to darker red, purple, and black. Quinoa has a thick, erect, woody stalk that may be branched or unbranched, and alternate, wide leaves that resemble the foot of a goose. Leaves on younger plants are usually green; but as the plant matures, they turn yellow, red, or purple. The root system develops from a tap root to form a highly branched system that makes plants more resistant to drought. Varieties of quinoa mature in 90 to 125 days after planting. Early-maturing varieties are recommended because of the unavailability of water at physiological maturity in water scarcity zones.

Reproductive growth

Inflorescence is a panicle that could present in green, purple, white, red or a mix of red and purple color (Fig 1). The panicle shape can be rounded as a glomerular shape, elongated as an amaranthiform shape or have an intermediate shape between round and elongated. The panicle can be loose or compact when the pedicels are long or short, respectively.Flowering usually starts 45-50 days after sowing and the flowering is of indeterminate type but wherever more moisture is available, secondary branches produce new flush from panicles. The flowers are of star fish shape, small, with two to three feathery stigmas and five stamens (Fig 2). The flowering window lasts between 12 and 15 days, in which each flower remains open for 5–7 days. Typically the flower blooms in the morning and closes in the evening after fertilization. The color of outer pericarp changes thereafter as the embryo forms and develops into mature seed. This gives rise to different color shades to panicle till maturity. The panicle and flowers are full of saponin exudates. The honeybees frequently visit the panicles during early morning hours to collect nectar from the freshly bloomed flowers.

Fig 1. Types of panicles observed in Quinoa experiment, ICAR-NIASM

Fig 2. View of Individual flower of Quinoa

Fig 3. View of Quinoa seeds

Quinoa is usually self pollinated, but cross pollination does occur at rates of up to 10 to 15%. Fruit development starts with fruit set which is defined as ovary thickening and the presentation of the first visible grains followed by the ripening process where the water content in the fruit i.e. achene varied, modifying its texture andchanging the pericarp color. This follows the plant senescence where the entire plant is dead and dry, and the product i.e. the seed is harvested.The seed is in size (0.8 to 0.11 in. in diameter) and has two flat surfaces and rounded sides (Fig 3). Seeds can be black, red, pink, orange, yellow, or white in color. The seed color is due to a resinous coating that contains two to six percent saponin. The embryo comprises 60% of the volume within the pericarp, and these results in the higher protein content of the seed in comparison to cereal grains. A general view of panicle growth behaviour from inflorescence emergence to fruit development and ripening is shown in Fig 4.

Fig 4. Panicle growth behaviour from inflorescence emergence to fruit dvelopment of Quinoa plant

Yield and market potential

The current market for quinoa in India is limited. A widespread effort is necessary to educate people in India about what quinoa is, how to cook it, how to process it to make value added products etc. Some of the farmers have already started growing the crop but the market is not well established to purchase the produce from farmer. The yield potential is very high if proper care is being taken and the monetary returns will be good provided processing units are established and the value added products are promoted widely. The cost of production for growers may decrease as they become more familiar with the crop and will obtain higher yields.

Potential quinoa consumers in India are concentrated in the urban areas, and to some extent sub-urban areas. Quinoa suits the fast moving lifestyle of city dwellers, providing all the essential nutrients from each and every segment of the food pyramid in a single dish. In 2017, India imported 0.42 USD Million worth of Quinoa from Peru, Ecuador, USA and United Kingdom. In supermarkets, it is sold for INR 1800-2000 per kg. Further, India has the second highest number of people with diabetes in the world, which is expected to increase to 101.2 million by the year 2030 (FAO). So consumers are looking to follow healthy lifestyles to obtain optimum nutrition to keep the diseases at bay, leading to an increased interest in nutrifood consumption. High nutritional quality, good flavor, and many uses in food products, give quinoa a good potential market. Prospective growers from areas with suitable environmental conditions should contact a marketing group about contracts for quinoa seed, before raising the crop.

Cultivation practices

Soil requirement

This crop grows well on sandy-loam to loamy-sand soils. Marginal agricultural soils are frequently used in South America to grow quinoa. These soils have poor or excessive drainage, low natural fertility, or very acidic (pH of 4.8) to alkaline (8.5) conditions. The murum type soil which having good drainage is also found suitable for growing this crop.

Weather conditions

- Quinoa requires short day lengths and cool temperatures for good growth. It can also be grown in marginal agricultural areas that are prone to drought and have soils with low fertility.
- Quinoa will flower earlier when grown in areas with shorter day lengths.
- Quinoa prefers neutral soils though it can also be grown in alkaline soils of pH 9.0 and acidic soils of pH 5.0.
- Ideal temperature for quinoa cultivation is around 18-20°C, however it can withstand temperature extremes ranging from 36°C to -8°C. Research reported that temperatures which exceeded 36°C tended to cause plant dormancy or pollen sterility and ultimately failed to set seed.
- This crop is very well responding to climate when sown duringrabi season (mid October-mid December) in India, contributing to higher seed yield.

Land preparation

Quinoa requires a level, well-drained seedbed in order to avoid waterlogging. The ridge and furrow system will give more yield as there is less probability of initial damage to seedlings due to water-logging. The murum soil should be free from big stones and should have good organic matter content to hold moisture for initial 8-10 days.

Manuring & fertilization

The FYM incorporation at rate of 15-20 tonnes per ha before land preparation will enhance the initial vegetative growth. A fertilizer dose of N: P: K @100:50: 50 kg per ha is recommended for good yield. Though Quinoa responds well to nitrogen fertilizer, it should not exceed 60 to 80 kg N/acre. Yields declined when greater levels of available nitrogen were present due to a slower maturity and more intense lodging.

Method of seed sowing

Seeds should be planted at a depth of 2 to 5 cm depending on soil type and available soil moisture. The small size of the seed (Fig 4) makes it susceptible to both dehydration and waterlogging when planted too shallow, or deep, respectively. Seed rate of 500 to 750gm per acre is sufficient to get good stand of crop. Seeding rates are usually doubled when growing conditions are not optimal. Better germination and requisite plant stand is obtained when the seeds are mixed with the sieved soil in the proportion of 1(Seed):3(Soil) (Fig 5). Better stands are obtained when seed is planted in a moist soil. Field trials indicated that increasing plant density resulted in a slightly earlier maturity, greater seed yield, and less -branching of plants.

Fig 5. Mixing of Quinoa seed & soil for sowing

Irrigation

This crop is somewhat drought tolerant. Studies on crop water use found that the application of lower amounts of water reduced plant height by 50% with only an 18% reduction in yield. Excessive irrigation after stand establishment usually produces tall, lanky plants with no yield improvement. Damping off and severe stunting of plants will occur with excessive irrigation in the seedling stages.

Pest and disease management

Disease and pest problems may arise after a crop like quinoa is introduced to a new production area. Viruses found on spinach or beets have been observed in quinoa fields. However, no proper research has been conducted to determine if any of those cause significant damage. A wide variety of insect pests can damage quinoa during seed germination up through harvest and seed storage but Entomologists do not consider insect problems to be a yield-limiting factor for quinoa production at this time.

Harvesting

Plants have a sorghum-like seed head at maturity. Harvest usually begins when the seed can barely be dented with a fingernail and plants have dried, turned a pale yellow or red color, and leaves have dropped. The seed should thresh easily by hand at this time. Field dry down is usually acceptable and plants are harvested easily.Rain during harvest will cause problems since mature seed will germinate within 24 hours after exposure to moisture. Generally an average yield of 5 to 15 q per ha is expected. An experiment at ICAR-NIASM on effect of sowing dates on yield of quinoa in 2017-18 indicated that sowing of the crop in first fortnight of December was superior resulting seed yield of 6 q ha-1 as compared to sowings in second week of November and first week of January.

Threshing and storage

The harvested panicles can be easily threshed with hammer and fanning mill. The panicles may be threshed under small tractor wheels and winnowed against the swift wind direction to separate stover from seeds. Smaller screens are used than with cereal grains due to the small size and lighter weight of quinoa seed. A fanning mill and gravity separator is usually necessary to remove trash from the seed.The seed must remain dry during storage. Prior to using quinoa in food processing, the saponins in the pericarp are removed by soaking them in water or by mechanical methods, such as with a rice polisher or a machine similar to those used to remove wheat bran.

In India, quinoa farming has bright future due to its high protein content and less carbohydrates compared to rice. Also there was no major incidence of disease and pest during the crop growth period which suggests that it can also be grown organically at the region. Ability of the crop to produce yield in degraded soil also indicates that it can be grown in fields where no other crop can be grown and will provide good return to the farmer.

View of Quinoa field at inflorescence emergence stage, ICAR-NIASM

View of Quinoa field at full flowering stage, ICAR-NIASM

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