POLICY DOCUMENT ON MANAGEMENT PRACTICES OF RAJMASH CULTIVATION IN HILLS

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मंत्री
कृषि एवं कृषक कल्याण
सैनिक कल्याण एवं ग्राम्य विकास विभाग
उत्तराखण्ड सरकार

उत्तराखण्ड सरकार

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प्राक्कथन

मुझे यह जानकर अत्यन्त प्रसन्नता हो रही है कि पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय, भारत सरकार के **"राष्ट्रीय हिमालयी अध्ययन मिशन"** के अंतर्गत पन्तनगर विश्वविद्यालय के वैज्ञानिक समूह ने पर्वतीय क्षेत्रों में राजमा की खेती के प्रबंधन एवं जैविक पद्धतियों को अपनाने हेतु एक पॉलिसी (नीति) दस्तावेज विकसित किया है। मैं किसानों से राजमा की खेती के लिए नीति दस्तावेज में दिए गए जैविक तरीकों के साथ–साथ राजमा उत्पादन की उत्तम तकनीकों को अपनाने की अपील करता हूँ। ऐसी जैविक पद्धतियों को अपनाने से पर्वतीय कृषि क्षेत्रों में निश्चित रूप से गुणात्मक सुधार होगा और किसानों के सामाजिक एवं आर्थिक उत्थान में मदद मिलेगी। मुझे आशा ही नहीं अपितु पूर्ण विश्वास है कि इन प्रयासों से प्रदेश के किसानों को राजमा उत्पादन में उन्नति के साथ–साथ विकास के नये आयाम प्राप्त होंगें।

मैं यह नीति दस्तावेज प्रकाशित करने के लिए परियोजना में कार्यरत मुख्य एवं सह–शोधकर्ताओं और उनके समूह को हार्दिक शुभकामनायें ज्ञापित करता हूँ।

"मंगलकामनाओं सहित"

(गणेश जोशी)

LT GEN GURMIT SINGH
PVSM, UYSM, AVSM, VSM (Retd)
GOVERNOR UTTARAKHAND

सत्यमेव जयते

RAJ BHAWAN
UTTARAKHAND
Phone : 0135-2757400
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22 August, 2023

Message

It is interesting to observe the remarkable initiatives spearheaded by the dedicated team of scientists at GB Pant University for Agriculture and Technology. The conceptualization of a comprehensive policy document focusing on "Effective Practices for Cultivating Rajmah in Hill Regions," guided by the National Mission of Himalayan Studies and supported by the Ministry of Environment, Forest, and Climate Change, Government of India, holds immense significance with in Uttarakhand's diverse agro-climatic zones.

Rajmah cultivation in Uttarakhand not only aligns harmoniously with the region's unique topography and climate but also brings forth many benefits. Beyond the essential practices of proper land preparation, timely sowing, diligent crop management, and harvesting at the optimal maturity stage, it enhances the region's food security by promoting the cultivation of a protein-rich staple. Additionally, rajmah is known for its soil-enriching properties, which contribute to improved soil health and sustainable farming practices.

Rajmah cultivation opens doors to increased income opportunities for local farmers. The promotion of value addition and connecting farmers with processors not only augments their earnings but also invigorates the local economy.

This manual is poised to be a valuable resource for all stakeholders, with a special emphasis on our hardworking farmers. My heartfelt appreciation extends to the Principal Investigators. Co-Principal Investigators, and the entire team responsible for the development of this policy document.

Gurmit

Lt Gen Gurmit Singh
PVSM, UYSM, AVSM, VSM (Retd)

गोविन्द बल्लभ पंत कृषि एवं प्रौद्योगिक विश्वविद्यालय
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कुलपति
Dr. M. S. Chauhan
FNA, FNASc, FNAAS, FNADS
Vice-Chancellor

Foreword

India is an agriculture-based country and holds first rank in the world for the production of pulses. In India, more than 65% of the population is directly or indirectly getting their income from agriculture. Therefore, agriculture greatly contributes to the economy of the Nation. However, agriculturally produced food is not sufficient for the ever-increasing population. Besides this, fragmented and insufficient agricultural land, pathetic agricultural practices, and poor agri-investment are major problems in agriculture that affect the yield and nutrition of the crop. It ultimately results in reduced farmer's income and causes malnutrition.

In order to conquer the problem current policy document was developed to achieve food and nutritional security and increase the income of hilly farmers through organic farming. This can be achieved through enhanced agricultural productivity, proper farm management, agro-processing, marketing, and community awareness. Apart from organic farming, types of bioinoculants/biofertilizers and their integration into agricultural practices for improving agriculture productivity and disease management also seem to be a possible solution for environmental sustainability. This policy document will serve as a vital tool for all who are involved in agriculture practices, agriculture-based industry, agriculture scientists, extension workers, researchers, and those teaching and studying organic-based crop cultivation.

I thank Ministry of Environment, Forest and Climate Change for funding the project under the scheme of the National Mission of Himalayan Studies. I wish to congratulate PIs and CoPIs of the project i.e Dr. Reeta Goel, Dr. Ajay Veer Singh, Dr. Navneet Pareek, Dr. Pankaj Mishra, Dr. Arun Kumar Jugran and their group has done a commendable job by developing the policy document on rajmash cultivation.

I earnestly hope that this policy document receives appreciation and could be resourceful for farmers and extension workers.

(M. S. Chauhan)

Date: 8 August, 2023
Place: Pantnagar

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Foreword

Agriculture is the food provider for the world's population. It also drives the economy of the nation because multiple industries and farmers rely on agriculture for raw materials. In India, the Himalayan region is under-explored and the agriculture practices adopted by the Himalayan farmers are conventional. Therefore, the Ministry of Environment, Forest and Climate Change has put interventions to advance agriculture practices to boost productivity and farmer's income under the National Mission of Himalayan Studies.

Rajmash is one of the important commodities of the hill region. Its nutritional value and unique taste make it a valuable cash crop. Beans offer a balance nutrition diet and the cheapest and most reliable source of protein and micronutrients mostly vitamin B, calcium, iron, and zinc. Rajmash is being cultivated in almost all districts of Uttarakhand. It is observed that the productivity of Rajmash in the hilly region is comparatively low over the plain region. This could be due to poor agronomic practices. The current policy document will help the farmer to enhance their knowledge of advanced agricultural practices. It also disseminates knowledge regarding the soil texture and nutrients which decide its need to flourish the growth of the crop. The policy document is also emphasizing practicing organic farming, especially on bioinoculants/biofertilizers applications which assist plant growth and development employing nutrient solubilization/mobilization. Moreover, selling opportunities were also described for farmer's welfare which will facilitate the better option for the farmer's for selling their crop produce. This consequently will defiantly boost the farmer's income.

I wish to thank the Ministry of Environment, Forest and Climate Change, which has initiated the National Mission of Himalayan Studies scheme and funded a project on the aspect of biofertilizers based rajmash farming practices in hilly regions. I congratulate everyone particularly the draft development team, reviewing team, and everyone who contributed directly and indirectly to the development of this policy document.

I hope that this policy document could be resourcefully used by farmers and extension workers to strengthen beans production.

(Ajeet Singh Nain)

Date : 8 August 2023
Place : Pantnagar

Er. Kireet Kumar
Scientist-'G' & Nodal Officer, NMHS-PMU
G.B. Pant National Institute of Himalayan Environment
(NIHE), Kosi-Katarmal, Almora, Uttarakhand

Foreword

It was the firm faith of the honorable Mahatma Gandhi that India lives in its villages. Even in the 21st Century, Agriculture is the basis of villager's income. But, because of the underdeveloped economic prospects in agriculture and other limitations, many farmers are quitting agriculture. On the other hand, food security and malnutrition are emergingas massive problemsinthe current world. To date, researcher/scientist have developed various varieties for obtaining the maximal productivity of the crops.But,still precision agriculture practices are needed to boost crop productivity and quality.

I am very happy that under the National Mission of Himalayan Studies (NMHS), the Ministry of Environment, Forest and Climate Change granted the multi-institutional project to the Department of Microbiology, College of Basic Science & Humanities, GBPUAT, Pantnagar and the PIs and CoPIsi.e.,Dr. Reeta Goel, Dr. Ajay Veer Singh, et al.have developed a policy document onscientific crop cultivation practices of rajmahand their selling opportunities, especially in the hilly areas of Uttarakhand.

Thispolicy document has been designed to improve agriculture practices in hilly regions. Adopting organic agriculture practices with advanced techniques would result in better crop yield. Moreover, the application of potential bioinoculants/biofertilizers, which can solubilize/mobilize accessible nutrients and prevent disease incidents, also provides a sustainable and organic solution for yield, nutrients, and quality improvement. Training of farmers for the precise application of potential bioinoculants/biofertilizers would make aware and also help them to advance their agriculture practices. It will not only be environment friendly but also enhance productivity and soil quality for sustainable agriculture.

At this juncture, I congratulate all the scientists and also hope for the great success and efficient utilization of the information presented in thispolicy document.

(Kireet Kumar)

Date : 8 August 2023
Place : Pantnagar

Preface

Agriculture and farmers are very crucial for Indian economy. Agriculture has shown their contribution to generate large scale employment and thereby influence country's GDP. Continuously growing population of India is largely dependent upon agriculture especially in rural areas of the country. However, in recent years, agricultural proportion to India's GDP has observed a decreasing pattern. Which has been observed to be regionally biased, cereal centric and resource intensive which is a major hindrance towards sustainable development. In last 40 years, injudicious and continuous use of agrochemicals has threatened human health and environment. Producing quality food in an environment friendly way from diminishing land as well as water resources is a formidable challenge of this century. Therefore, agriculture needs to be revitalized along with innovative technologies to enhance the productivity in sustainable manner. New methodologies that utilize all the elements of the agricultural system are required which include enhancement and exploitation of beneficial soil microbial populations and better soil management.

The policy document intended to advancing agriculture practices in hilly regions. Therefore, it collectively discussed the all the step required for rajmash cultivation including scientific practices of land preparation, seed varietal selection, seed sowing method, disease management and selling opportunities of produce. It also emphasises on usage of bioinoculants/biofertilizers with rajmash crop to promote sustainable farming practices. The policy document is constructed and arranged in such a way, so that a wide range of farmers could adopt the advanced farming practices with different selling opportunity. This policy document could serve as the reference guide for farmers and for extension workers also.

Author

Date: 8 August 2023

CONTENT

1. Introduction

In view of the evergrowing population of the world, this is expected to become 9.6 billion people by 2050. It is projected that around 70% more food is needed to meet the food requirement. This food demand is mainly arising from developing countries (Alexandratos and Bruinsma, 2012). The production of all crops must be increased at the worldwide level to overcome these challenges. Population of developing countries are primarily depends upon legumes for proteins. Because legumes are fully fledged with proteins and minerals and therefore regarded as central crop of agricultural systems. Legumes have a significant role in human diets (Akibode et al., 2011). Among the legumes, rajmash also known as kidney bean (*Phaseolus vulgaris* L.) is one of the most widely grown and popular vegetables in India. Rajmash are primarily grown for their edible seeds and pods all over the world (Aydin et al., 2019). The young, green pods of rajmash are consumed as a vegetable. Immature pods are marketed fresh, sold whole, sliced, or French-cut, in fresh, frozen, or canned form. It endows with 15% of protein and also accomplishes around 30% of caloric requirement to the world's population (McConnell et al., 2010). Due to the awareness regarding the crop's nutritional status and market prices, rajmash cultivation has gained the attention of farmers and researchers. Therefore, currently in India rajmash is cultivating in an estimated area of 90,000 ha. In India, average seed yield of rajmash ranged from 421- 1,000 $kgha^{-1}$ (Gupta et al., 2019). In contrast, under proper management practices the average yield of rajmash recorded from 1400-1700 kg ha^{-1} (Kalro, 2008; Mwangi et al., 2019). On contrary, the international average yield of rajmash recorded in the range from 1,500-2,000 kg ha^{-1}, which seems that the average yield of India is comparatively lower than international status (Gupta et al., 2019). In India, Jammu and Kashmir, Himachal Pradesh, Karnataka, Kerala, Maharashtra, Uttarakhand, West Bengal, Tamil Nadu, and Uttar Pradesh are the major rajmash growing states. Concerning to bean production, Gujarat, Bihar, Jharkhand, and Karnataka are considered as largest producer of bean with a production of 751.99, 244.55, 200.82, and 166.76 thousand tones, respectively (https://agriexchange.apeda.gov.in/India%20Production/India_Productions.aspx?hscode=1067). Rajmash is typically grown in the hills of the Himalayan region during the month of Kharif, although better management makes it possible to produce a large yield in the lowlands during the month of Rabi. However, rajmash cultivation during rabi and summer is also gaining popularity in northern Indian plains. According to FAO, the total area of common beans harvested worldwide in 2019 was 33.1 million ha, and their production was 28.9 million tonnes (WHO, 2020). It has been reported that around 50% of the global common beans production shared by Asia, in which Myanmar, Brazil, India, China, and America are the top five producer countries during 2000–2019. Over the last five years, production has grown at an average rate of 10% per year. In view of the productivity status of rajmash and ensuring the food security of the world, improved production of rajmash is necessary for enhancing farmer's income, food security, and the economy of the nation. Therefore, the policy document target to summarize the cultivation practices of rajmash and key precautions/ recommendations for augmenting the production and commercial value of the crop.

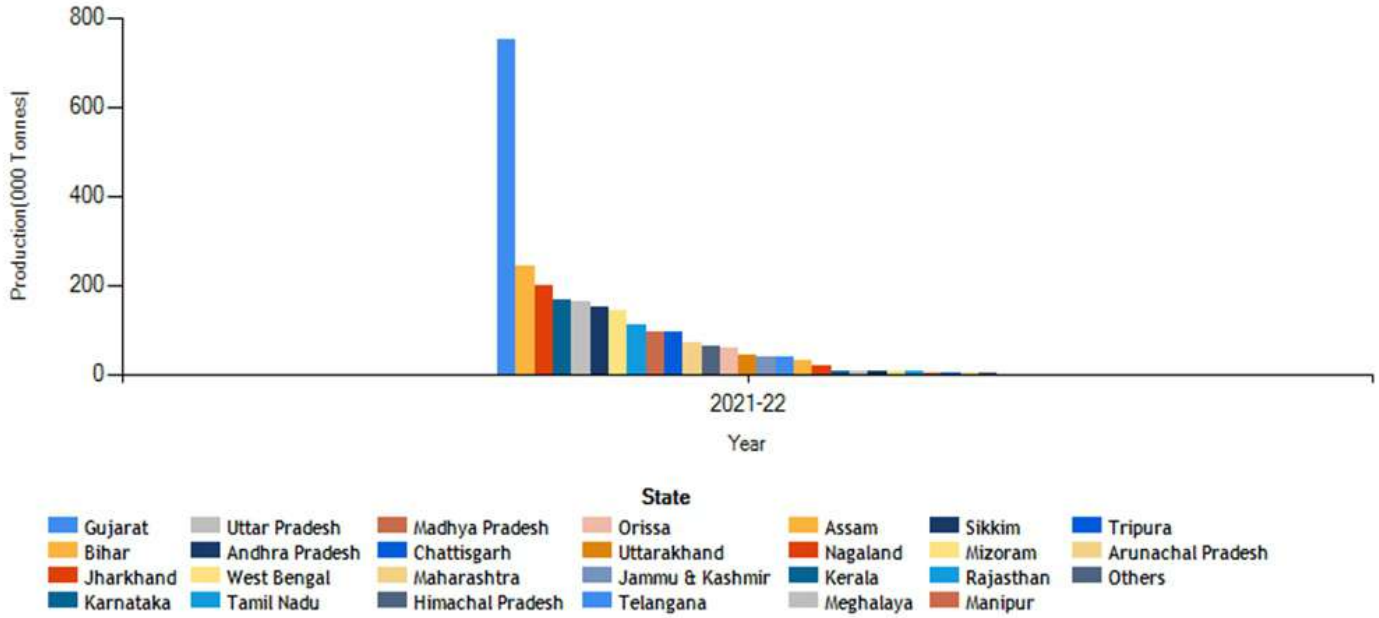


Fig. 1. Production of beans in different states of India
Source: The Agricultural and Processed Food Products Export Development Authority (APEDA)
https://agriexchange.apeda.gov.in/India%20Production/India_Productions.aspx?hscode=1067

2. Problems associated with rajmash production

Rajmash (*Phaseolus vulgaris* L.), is one of the most important grain legume crop for direct human consumption. But the cultivation process is associated with many challenges. There are hundreds of *Phaseolus* varieties grown in hilly areas and all these varieties required different climate, soil requirement and have a good potential of yield and nutrient. Moreover, most of the hilly areas soil has steep and rugged topography, which leads to low concentrations of available nitrogen, phosphorus, potassium, enzyme activity, etc. Apart from this, with increasing altitude, the soil depth also decreases which in turn leads to the uneven distribution of nutrients and other solutes in soil which resulted into decreased production. The biotic and abiotic factors are the other major constraints for rajmash cultivation (Assefa et al., 2019). Numerous bacterial, fungal, and viral diseases, as well as several insects and nematode pest, are among the biotic factors that affect production of rajmash. Abiotic challenges include drought, heat, cold, and toxic or deficient soil nutrients which also severely reduce production (Assefa et al., 2019). The Rajmash root system is very weak and is more susceptible to root diseases like bacterial wilt, common blight, *Fusarium* root rot, *Fusarium* wilt, halo blight, rust, and white mold, which is also one of the most important problems associated with rajmash production. The farmers are needed to be aware about the scientific and précised practices of rajmash cultivation and bioinoculants application for nutrients and yield improvement. In this view, more than 30 trainings and awareness programs were conducted to sensitize farmers for rajmash cultivation management, cultivation practices and bioinoculants/biofertilizers application methods under the project entitled "Characterization of Kidney Bean (Rajmash) Rhizosphere

Microbiome from Higher Altitude of Indian Central Himalaya" funded by NMHS, MoeF&CC, Government of India running at G. B. Pant University of Agriculture & Technology, Pantnagar, But still a handful area of Uttarakhand could be covered through the farmer's awareness cum trainings program because numerous farmers of Uttarakhand are still untouched.

Glimpse of bioinoculants/biofertilizers awareness trainings and workshop program conducted during 2019-2023 under NMHS funded project

3. Context and goals of policy

Rajmash is an important cash crop in the hills. For efficient management of nutrients in the soil, utilization of bioinoculants/biofertilizers for rajmash cultivation can significantly increase the yield. Because potential bio-inoculants facilitate plant growth and development by making essential nutrients available to the plants and improves the soil health by maintaining soil bio-diversity. Under the normal practice of rajmash cultivation, farmers are advised to follow and grow the rajmash under recommended climate, soil and land, nutrient and irrigation condition. Further distance between plant-to-plant and row-to-row distance are also needed to be taken care. The goals of the policy are enumerated below -

(i) Create awareness and train farmers for precised advanced scientific agricultural practices of rajmash cultivation.

(ii) To introduce farmers with the importance of soil health, nutrient requirement, and better management for crop production improvement.

(iii) To protect and improve the land, water, soil bio-diversity, and other resources essential for increasing the productivity, profitability, and stability of farming systems.

(iv) To aware and train farmers for bioinoculants/biofertilizers importance and their field application methods.

(v) To introduce farmers with various diseases of rajmash and their prevention measures.

(vi) To introduce farmers for selling opportunities and post-harvest management to enhance their socio-economic status.

4. Crop description

Kingdom	*Plantae* - Plants
Subkingdom	*Tracheobionta* - Vascular plants
Superdivision	*Spermatophyta* - Seed plants
Division	*Magnoliophyta* - Flowering plants
Class	*Magnoliopsida* - Dicotyledons
Subclass	*Rosidae*
Order	*Fabales*
Family	*Fabaceae* L. - Pea family
Genus	*Phaseolus* L. - bean
Species	*Phaseolus vulgaris* L. - Rajmash
	(Source- United States Department of Agriculture USDA)

The genus *Phaseolus* belongs to the family Fabaceae or Leguminosae, subfamily Papilionoideae. *Phaseolus vulgaris* is a herbaceous annual plant grown worldwide for its edible dry seeds or unripe fruit. The rajmash show continuous variation in the growth habit from determinate bush to indeterminate climbing cultivars. Rajmash growth habits are classified into four major classes using the type of terminal bud (vegetative vs. reproductive), stem strength (weak vs. strong), climbing ability (non-climber vs. strong climber), and fruiting patterns (mostly basal vs. along entire stem length or only in the upper part) (Singh, 1982), These are the Type I= determinate upright bush, Type II= indeterminate upright bush, Type III= indeterminate, prostate, non-climbing or semi-climbing, and Type IV= indeterminate, strong climbers. Rajmash (*P.vulgaris*) and wild *Phaseolus* species have 2n= 2x = 22 chromosomes. The *P. vulgaris* chromosomes are extremely small, and all 11 chromosomes have been identified. The Rajmash has one of the smallest genomes in the legume family with 635 Mbp size (Singh, 1982). The plant of rajmash can be studied into following:

i) Root

The root system of the rajmash is composed of a taproot, adventitious roots, and an umbrella of basal roots upon which the rest of the root system develops through lateral branching. The root is the main component of the plant

which is involved in nutrient and water uptake. The root portion of the rajmash exhibits morphological and anatomical differentiation from tip to base which is classified as root's tip, elongation zone, maturation zone, and mature zone. Root tip part consist root cap and meristematic region, which is thought to have a large nutrient demand (Clarkson, 1996). In the maturation region of the root, root hair develops from epidermis and takes part in nutrient uptake (Rubio et al., 2004). The plant of rajmash exhibits around 3 feet deeper widely branched root system, in which the central horizontal root branches create lateral spread of up to 30 inches, by which it can efficiently function for nutrients and water uptake from the soil upto 20 inches.

ii) Stem

The main stem derives from the axis of the seed embryo. The number of branches and branching pattern may vary greatly depending on the genotype and environment. More than 50% of the pods are borne on branches.

iii) Leaves

Rajmash is an annual herb in the family of legumes. They are climbers having compound and broad leaves. The leaves grow alternately on the stems, are green or purple and divided into 3 oval leaflets with smooth edges. The leaves could be 6–15 cm (2.4–5.9 in) long and 3–11 cm (1.2–4.3 in) wide. The two unifoliolate leaves borne above the cotyledonary node are opposite to each other followed by one trifoliolate leaf at each node in an alternate phyllotaxy. The fully developed trifoliolate leaf has a long petiole(> 7 cm), a small petiolule (< 3 cm), very small pulvini, and three leaflets of which the central one is often symmetrical and chordate, ovate, or lanceolate.

iv) Flower

The inflorescence of rajmash is a pseudoraceme. Flowers are cleistogamous and normally are highly self-pollinated. Most species bear five-petaled flowers with a distinctive papilionaceous or butterfly-like shape. The flowers have a single large upright petal, flanked by two horizontal “wing” petals, and subtended by two petals at the bottom of the flower, partially or completely joined to form a boat-like “keel.” Flowers typically have ten stamens, nine of which may form a tube surrounding the ovary and one that is separate from the others and positioned above the ovary. The Rajmash produces white, pink, lilac or purple flowers which are approximately 1 cm (0.4 in) in diameter, Bilabiate calyx is small (< 5 mm) with the upper two teeth united. The two keels may be coiled up to two times. There is a single vexillary stamen (a distinctive arrangement in which one giant stamen covers the other smaller petals) on the upper side and nine stamen united into a long sheath or tube around the style. The stigma tends to extend around the tip of the style.

v) Pod

Mature pods are straight to slightly curved with three to six seeds. The size, shape, and colour of pods and seeds can vary greatly. The pods of rajmash are 8–20 cm long and 1–1.5 cm wide, which can vary in color from green

to yellow or black to purple or bicolor with or without stripes at the outer base.

vi) Seed

Rajmash seeds have epigeal germination. The epigeal germination is a type of germination in which germination of seed takes place above the soil. The hypocotyl elongates rapidly and moves upward pulling the cotyledons and these cotyledons fall off a few weeks after emergence.

vii) Nutritive value

The rajmash is a nutritious food crop and a major source of protein throughout the world. The nutritional value of rajmash per 100g is Carbohydrates (60.01 g), Sugars (2.23 g), Dietary fiber (24.9 g), Fat (0.83 g), Protein (23.58 g), Vitamins which include Thiamine (B1)(46%) 0.529 mg, Riboflavin (B2)(18%) 0.219 mg, Niacin (B3) (14%) 2.06 mg, Vitamin B6 (31%) 0.397 mg, Folate (B9) (99%) 394g, Vitamin C(5%) 4.5 mg, Vitamin E (1%) 0.22 mg, Vitamin K(18%) 19 g, Minerals including Calcium (14%) 143 mg, Iron (63%) 8.2 mg, Magnesium (39%) 140 mg, Phosphorus (58%) 407 mg, Potassium (30%) 1406 mg, Sodium (2%) 24 mg, Zinc (29%) 2.79 mg (Parmar et al., 2016). Rajmash are mainly composed of starchy carbs, which account for approximately 72% of the total calorie content. Starch is predominantly made up of long chains of glucose in the form of amylose and amylopectin. Rajmash are high in fibre and also provides insoluble fibres known as alpha-galactosides. Raw or undercooked beans contain a toxic protein called phytohemagglutinin (PHA).

5. Variety selection

Rajmash is grown in the plains as well as in hilly regions ranging from plains to an altitude of 3500 m above sea level. Along with the altitudinal gradient different varieties of rajmash are also cultivated. The rajmash varieties are classified into two groups, which include dwarf or bush types and climbing or pole types. In Asia (particularly in India) Pusaparbati, Arka Komal, Jampa, Bountiful, Prider, Pencil wonder, and Contender are grown under the bush type category whereas VPF-191, Keatuki wonder, and premier varieties are grown under the Pole type category. State-wise recommended rajmash varieties are HUR-137, Malviya Rajmash-137 in Uttar Pradesh, Varun (ACPR-94040), HPR-35 in Maharashtra, IPR 96-4 (Amber) in Bihar, Ankurin Rajasthan, ArkaAnup in Karnataka, Gujarat Rajma-1in Gujarat and VL Rajmash 125, VL Bean-2 in Uttarakhand.

Bush type

The bush-type rajmash grows approximately two feet high and does not require any support. The bush type varieties grown in hills are YCD 1, Ooty 1, Ooty (FB) 2, Arka Komal (Sel.9), Premier, Arka Bold, Arka Sampoorna, and Arka Karthik are popular varieties while in plains Arka Komal, Premier (Sel.9), Arka Suvidha, Arka Anoop, Arka Samrudhi, Arka Suman are under cultivation. Bush varieties form erect bushes of 20–60 cm (8–20 in) tall. VL Rajma 3 and VL Rajma 125 are bush type varieties grown in hilly area of Uttarakhand. VL

Rajma 3 variety is sown in rainfed organic conditions and their grains are light red in colour with deep red patches. It has an average yield of 10-12 q/ha, while VL Rajma 125 is a high yielding rajmash variety suitable for cultivation under rainfed conditions of Uttarakhand hills. VL Rajma 125 is a white grain coloured variety has an average yield potential of 11-12 q/ha.

Pole type

Bush Type

Pole type

Pole-type rajmash are also known as runner beans that grow tall on climbing vines (a plant whose stems require support) of 2–3 m (7–10 ft) long. Anupam, Pusa Parvati and local variety Tangkhul hawai are some of the improved variety of pole type rajmash (KVK, Ukhrul, ICAR Research Complex for NEH region).

6. Strategies and management practices for maximal rajmash production

Rajmash have an excellent source of high-quality protein, essential amino acids, fatty acids, minerals, and vitamins. Rajmash occupies an important place in human nutrition, especially among people with low income. The development and improvement of low-cost legume production management practices require more focus to make them suitable for Indian farmers with limited resources. Growing rajmash as a seed legume in dry-land rotations with winter wheat and maximizing soil-related parameters can boost the bean production in many developing nations. The most promising technologies for producing rajmash include enhanced crop establishment and management techniques, integrated soil fertility and pest management techniques, etc., which increase productivity and profitability together with the ensuring social and environmental sustainability and food security. The farmers can improve the cultivation of rajmash in hilly areas by adopting appropriate agricultural management practices, which include land preparation, sowing method, microbial treatment, nutrient management, crop irrigation, weed control, disease management, etc. A brief insight into the management and cultivation practices of rajmash in hilly areas with the help of bioinoculants/ biofertilizers

application is described below.

6.1 Climate

Rajmash are self-pollinating crops and do not need bees for fruit production. Their flowers have all the needed reproductive parts and can transfer and accept their own pollen for the development of their edible fruits. Rajmash grow best with a temperature of around 15˚C to 30˚C. The rajmash plants are very much responsive to temperature variations, and the plants grow well in tropical and temperate areas. Rajmash is grown in the hilly region during kharif and in lower hills/tarai region, sown as spring crop. Areas receiving 60-150 cm of annual rainfall are ideal for the growth of plants (Parmar et al., 2016). In north-east plains and hilly tracts of Maharashtra, it is cultivated during Rabi. The ideal temperature range for proper growth of rajmash crop is 15°C-25°C and harvesting temperature is 28°C-30°C (https://www.agrifarming.in/kidney-beans-farming). It is highly sensitive to frost and water logging. Above 30°C, the flower drop is a serious problem. Similarly, below 5°C the flowers and developing pods and branches may damage (http://dpd.gov.in/Rajmash.pdf).

6.2 Soil types and land preparation

Soil and land preparation is the basic and very important stair for rajmash cultivation. A well watered loamy soil of a pH ranged from 5.5-7.0 under a cool climate is suitable for rajmash farming (https://vikaspedia.in/agriculture/crop-production/package-of-practices/vegetables1/ french beans). Although, rajmash can grow on almost all types of soil, but loams and clay loams soil types are best for obtaining better yields. If the cultivating land soil is acidic in nature then soil must be treated with lime before sowing. For land preparation, tillage is necessary step for the manipulation of soil with farm tools and implements for obtaining ideal conditions for seed germination, seedling establishment, and growth of crops (Das et al., 2014). The main aim of tillage is to produce good soil conditions and tilth for crop establishment and initial root and shoot development. Rajmash having bold and hard seed coat needs a good seed bed accomplished thorough primary tillage like ploughing, harrowing or discing and planking. A good seed bed i.e. friable but compact soil, adequate moisture, and free from weeds and plant debris of earlier crops is required for better crop cultivation. For the preparation of the field, the soil is ploughed 2 - 3 times with a power tiller or with the spade. Planking is done during the last ploughing to make a friable soil bed for sowing. Soil is dug thoroughly and farm yard manure (FYM) is incorporated and forms beds of convenient size.

Land preparation

Sowing method is also vital factor that has a direct effect on seed requirement, plant establishment, cultural operations, and efficiency of production inputs. These rajmash seed varieties have 3-6 seeds per pod at maturity. The sowing time for kharif season in the hills is the last week of May to the first week of July and for spring in the lower hills, it is 2nd fortnight of March. The dibbling method of sowing rajmash seeds is mostly used in hilly

areas. 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. The dibbling method facilitates the practice of conservative tillage and reduces the chances of soil erosion. Dibbling method requires fewer seeds, and it gives rapid and uniform germination with good seedling vigor. Intercultural practices like weeding, earthing up, and care of individual plants can be facilitated. After final land preparation, the field should be divided into plots of convenient size, and ridges and furrows are open. Besides this, broadcasting method of sowing is also followed by farmers. This broadcasting method requires more quantity of seeds and the weeding process is also a difficult job in this type of sowing.

Line sowing method

Dibbling method

6.3 Pre-sowing

Before sowing of seed, the soil of the prepared land needs various practices to control the pathogens and weed population. In order to minimize nematode populations, soil-borne diseases caused by pupae and propagules and to reduce weed infestation, deep ploughing of the fields are extremely needed throughout the summer. Soil solarization and timely sowing also help in better crop production. Soil solarization is a non-chemical, eco-friendly way of pest control. Solar energy is used to increase the soil temperature to level at which many soil-borne pathogens either killed or greatly weakened. Soil solarization is used to weaken or kill bacteria, fungi, nematodes, insect and mite pests along with weeds present in the soil. In widely used method of solarization is mulching or covering the soil with a tarp, which is usually done with a polyethylene cover. The solar energy gets trapped into it and causes physical, chemical, and biological changes in the soil residing community (Stapleton, 2000). Soil solarization is based on the exploitation of solar energy for heating wet mulched soil to the temperature of 40°C–55°C in the upper soil layer. Ecological engineering for pest management is a new paradigm to enhance the natural enemies of pests in an agro-ecosystem and relies on the use of cultural techniques to bring about habitat manipulation and enhance natural enemies of pests in the crop. Ecological engineering should be adopted by growing the recommended attractant, repellent, and trapping crops around the field bunds. Farmers should grow marigolds or peas as a trap crop to control leaf miners. For the control of aphids, planting of tall border crops like mustard, and crop rotation with non-leguminous crops, particularly cereals should be carried out. Farmers are suggested that before sowing, seeds should be treated with *Trichoderma* 4 g/kg or Thiram or Carbendazim @ 2 g/kg of seed 24 hours to control fungal diseases at severe conditions.

6.4 Seed and sowing

In hills, the 70-80 kg/ha seed rate should be applied to the fields for the kharif season while rajmash distance between two consecutive rows and distance between two consecutive plants should be 45-50 cm and 8-10 cm, respectively and for Rabi and Spring season distance between two consecutive rows and distance between two consecutive plants should be 40 cm and 10 cm (irrigated); 30 cm and 10 cm (Rain fed), respectively. Seeds should be sown at the soil depth of 6-7cm. Light irrigation is required after 2-3 days of sowing. Perfect sowing is placing the seed at a specific depth with the correct amount of seed per unit with optimum spacing between plant to plant and row to row (https://www.apnikheti.com/en/pn/agriculture/crops/pulses/kidney-bean-rajma). Pole-type varieties should be sown at a distance of 1m in the hills at the rate of 3-4 plants per hill. If the rajmash crop is raised for the first time it should be treated with *Rhizobium* (https://www.apnikheti.com/en/pn/agriculture/crops/pulses/kidney-bean-rajma).

6.5 Microbial treatment

Microorganisms are minute, unicellular organisms that are invisible to the naked eye. Microorganisms play a fundamental role in the agriculture system by improving agricultural productivity through direct nutrient supply, production of plant-growth-promoting substances, and increasing plant tolerance to abiotic stresses. The bioinoculants are comprised of living or latent cells of microorganisms that multiply under favourable environment and act positively on plant's health. In other words, bioinoculants are regarded as plant growth-promoting microorganisms (PGPM), because they facilitate plant growth by making essential nutrients available to crops (Etesami et al., 2017). Different inoculants are used individually or in combination with different types of microorganisms as consortia for evergreen agriculture. Commercially beneficial bioinoculants are available in the form of bioformulations all over the world and known as biofertilizers (Maitra et al., 2022). Bioformulations are biologically active substances derived from microbial biomass or product-containing microbes and their metabolites that could be used in plant growth promotion, nutrient acquisition, and disease control in an eco-friendly manner. Bioformulations or biofertilizers contain living microbes such as bacteria and fungi. These can be used alone or in a combination with chemical fertilizers.

In the study conducted by G. B. Pant University of Agriculture & Technology, Pantnagar under the project entitled "Characterization of Kidney Bean (Rajmash) Rhizosphere Microbiome from Higher Altitude of Indian Central Himalaya" funded by NMHS, MoeF&CC, Government of India, four potential bacterial isolates namely *Pseudomonas jesseni* MP1, *Pseudomonas palleroniana* N26, *Pseudomonas lurida* NPRP15 and *Pseudomonas* sp. PPERs23 were demonstrated and applied with rajmash in the farmers fields of Uttarakhand located at Harsil (Uttarkashi), Chakrata (Dehradun), Triyuginarayan (Rudraprayg), Lata (Chamoli), Kilashpur (Chamoli), and Parsari (Chamoli). The findings from the study demonstrated that all the bacterial isolates significantly improved the yield and nutrient status of rajmash. Besides, the augmentation in the soil health was also reported at all demonstration sites of the project. Therefore, in order to improve the yield along with maintaining the environmental sustainability and soil health, the application of such potential bioinoculants in the form of biofertilizer is recommended to maintain organic farming in the state. Besides this, some commercially available bioformulations are as follows (Mehnaz, 2016).

a) JumpStart developed by Novozymes company contains the fungus *Penicillium bilaii* that improves the availability of phosphate to the plants.

b) TagTeam is a multi-action inoculant developed by Novozymes company, specifically for legumes. It makes better use of phosphate and improves nodule formation providing more fixed nitrogen. It is a combination of rhizobia strains with *Penicillium bilaii*. This product is available in granular, peat, and liquid formulations for use on peas, lentils, chickpeas, soybean, and dry bean.

c) RhizoMyx is an endomycorrhiza inoculant designed to improve plant performance by increasing root development to improve nutrients and water uptake.

Numerous crops are cultivated in different climatic conditions and their native mode of sowing/planting and growth is associated with them. As per the sowing/planting conditions and accessible components (root, seed, shoot, leaf) of plants for bioinoculants application, several methods are being used and discussed below:

A) Seed treatment:

A popular and useful application strategy for protecting seeds and seedlings from soil- and seed-borne diseases is microbial treatment of soil before sowing. Bioformulations must be applied carefully to the seeds for effective treatment. In seed priming, the slurry method is usually used to apply the powders and granular form of bioformulation to the seed. This method involves mixing the solid with a strong adhesive solution to form a slurry, which is then applied to the seeds. Liquid inoculants (generally supplemented with adhesives) are typically sprayed onto the seeds. Adhesives commonly used for seed coating include Arabic gum, CMC, hydroxypropylmethylcellulose, starch, wheat flour, sucrose, vegetable oils, and non-toxic commercial preparations. Sometimes a superfine powder of limestone ($CaCO_3$) is added immediately after coating. Seed

coatings can be performed either by hand, rotating drums, large dough cement mixers, mechanical tumbling machines or automated seed coaters. If the coating is inadequate, melted jaggery and other adhesives can also be employed to ensure that bioinoculants adhere to seeds properly. For effective adhesion, after mixing seeds must be dried for 30 minutes under shade. Coating and drying can also be performed simultaneously in fluidized beds (also called fluid bed dryers, it is used to reduce the moisture content of powder and granules) and seed coaters with integrated dryers by dispersing the seeds on a cushion of pressurized air while applying the formulation. A major constraint of this application technique is that seeds can be coated only with a limited amount of inoculant, which can be a limiting factor. Moreover, if the inoculant is not well attached to the seed, some seeds may be lost during sowing. Afterward, seeds can be sowed in the fields. As soon as seeds are sown, coated bioinoculants multiply, and protecting plants against diverse agricultural seed diseases and boosting plant vigour and growth. The factors influencing microbial survival on seeds are the release of toxic exudates from the seed coat or incompatibility between the inoculant strains and seed-applied chemicals (Bejarano and Puopolo, 2020).

B) Soil treatment:

Different microbial treatment techniques can be used to apply bioformulations or biofertilizers to the soil. First is the direct approach, in which biofertilizers are sprayed directly onto the prepared soil bed i.e. 2-3 cm below the surface. Conversely, in the second procedure, compost and biofertilizers are mixed initially and then let to grow overnight. Then, at the time of sowing, this bioformulation comprising compost is applied to the field. Soil treatment is mainly done when the microbial component of bioformulation is sensitive to desiccation. In order to treat soil, a predetermined dosage of bioformulations is combined with a specific amount of soil, which is typically determined by the bioformulations microbial load and the soil's physicochemical characteristics.

Some precautions must be followed while using bio inoculant for the cultivation of rajmash which includes:-

i) Bioformulation packages need to be stored in a cool and dry place and away from direct sunlight and heat.

ii) The bioformulation must be applied within 18 to 24 hours of being combined with water or other chemicals.

iii) The right amount of mixture needs to be made between the diluting and adhesive agents.

iv) To prevent contamination from other microbes, the bioformulation must contain the efficient strain, and its suspension must be prepared in a clean container.

v) Sow the treated seeds immediately, preferably in the morning or afternoon avoiding scorching sunlight.

vi) The package has to be used before its expiry and always use the recommended method of application.

6.6 Nutrient management

A balanced supply of nutrients in adequate amounts and available forms holds the key to successful crop production. Fertilizer management encompasses adding the right amount of nutrients at right time through an appropriate method to minimize nutrient losses, thereby, making efficient nutrient use for enhancing crop productivity and maintaining soil fertility (Dass et al., 2014). The fertilizers requirement depends upon the type and nutritional status of the soil. In contrast, some general recommendations are mentioned in the following section:

Recommended N (Nitrogen), P (Phosphorus), K (Potassium) ratio of fertilizer to be applied in the rajmash field should be 90-120: 60-80: 50 (NPK – Kg/ha) for proper growth of the crop. The full dose of P&K and half dose of N as basal dose should be applied initially, while the remaining N should be applied at the time of flowering. But in order to maintain the soil health and environmental sustainability, a stepping towards the organic state, farmers have to shift gradually to the organic based fertilizers. In which, farmers needs to apply farm yard manure (FYM) at the rate of 20-50 t/ha and potential biofertilizers as per the recommendation of manufacturer. Biofertilizer contain beneficial microbial inoculants to increase soil nutrient availability. Moreover, the integrated approach in which bio-fertilizers combined with small amount of NPK fertilizer reported to increase macro and micro nutrients availability and optimized plant growth and productivity. Application of synthetic fertilizers is only recommended when soil suffers with nutrient deficiency or organic fertilizers are not enough to satisfy the nutritional requirement of the crop.

6.7 Crop irrigation

Rajmash seed has a short root system and is susceptible to both conditions of water stress and flood. A good crop can be obtained if a little moisture remains even in the rainy seasons. Therefore, pre-sowing irrigation should be given for better germination of rajmash seed. Six to seven irrigations are required during the growing season. Irrigation on the twenty-fifth day after sowing and three irrigation at the twenty-fifth days interval are necessary to get optimum yield. Irrigation in the rajmash crop is required before blooming, during flowering, and at the pod development stage. Water stress at these stages will lead to a yield loss of rajmash. Deform pods can resulted from water stress due to low moisture or excessive evaporation loss.

6.8 Aftercare

The bean starts flowering after 45 days. Therefore, the plant's field should be weed-free. Hence, weeding should be done during 20-25 days and 40-45 days after sowing. After being harvested, rajmash require only minimal processing. Rajmash should be sorted and get rid of any harmed or diseased ones before storing them. Beans should always be stored in a cool, dark, and dry place because heat and humidity can cause quality to decline. The crop should be earthed up after each weeding. Generally, Pole type cultivars are grown in hilly areas and

grow well on a support made of cane frames. They could be also supported by erecting wooden poles connected with strings.

6.9 Weed control

Initial growth period is crucial for crop growth and during this period weed infestation should be avoided for the proper growth of the plants. Integrated Weed Management (IWM) is basically the integration of effective, dependable, and workable weed management practices such as cultural (hand weeding), mechanical, chemical, and biological approaches/methods that can be used economically by the farmers (Pooniya et al., 2015). Complete weeding operations should be synchronized along with fertilizer and irrigation operations. If necessarily required, use weedicide Fluchloralin@ 800mL/acre or Pendimethalin@1ltr per acre as pre-emergence of the weed.

Crop management and weed control

7. Crop stages

7.1 Germination

Germination is the process in which a seed sprouts, or begins growth. Seed germination can occur after a period of dormancy and is affected by available light, water, air, and many other variables. The germination period of a bush-type rajmash is approximately 7 to10 days depending on growing conditions and pole-type rajmash

seedlings emerge in 8 to 10 days. The germination process of the rajmash requires water (for splitting the rajmash coat), sunlight, and eventually soil for support and rooting.

i) Seed coat rupture and emergence of the radicle

In the first phase of the germination of a rajmash seed, available water saturates the seed through the micropyle causing the seed to swell. The micropyle is a small pore located on the seed coat through which water is absorbed. As water is absorbed and the seed swells, the seed coat becomes brittle and begins to pull away and wrinkle. As the seed coat continues to swell, the seed coat eventually breaks, and allowing the radicle to emerge. The radicle is the embryonic root of the plant that emerges and grows down into the soil. The tip of the radicle is called the root cap. The root cap protects the root as it pushes its way through the soil. The cells that make up the root in the meristematic region divide rapidly and undergo elongation and enlargement and are responsible for the growth of the root.

ii) Maturation of the root system

After the emergence of the radicle, the root system begins to develop. The rajmash plant grows a taproot, adventitious roots, and an umbrella of basal roots fibrous root system, meaning that it has many branches. The different branches of roots occupy a large amount of soil in a shallow, compact area at the base of the plant. The main root, or primary root, becomes the longest root and uses a root cap to push through the soil. From the primary root, the secondary root system emerges, sometimes called the lateral system. These laterals provide stability for the plant and absorb water and nutrients from the soil. In a fully mature plant, the roots will extend to approximately 24 inches. The small, hair-like structures, are called root hairs which absorb water and minerals for the growth and development of the plant.

iii) Growth of the hypocotyl

The hypocotyl is the stem of the germinating plant. It is the area of the plant located between the radicle and the cotyledons. The hypocotyl is considered an "extension" organ and pushes the seed coat and cotyledons through the soil and above ground to continue maturation. The stem is influenced by the phenomenon of phototropism, which means that the hypocotyl will grow toward the direction of sunlight. The hypocotyl will eventually develop into a plant stem and act as a support structure. The stem is also a vascular structure, meaning that it carries water and nutrients from the roots to shoots for the growth of the plant. The stem is made up of nodes and internodes. The nodes are the buds that are converted into flowers. The internodes are the distance between the nodes. Ultimately, stem tissue called meristem develops into new plant cells as the plant grows.

iv) Emergence of the first leaves

In this phase of growth, the first rajmash seed leaves begin to mature. The green rajmash seed is considered a dicotyledon, meaning that it produces two seed leaves within the cotyledons. The process of germination of a

rajmash is also called hypogeal germination. This means that the cotyledons mature above ground rather than below. The purpose of the leaves is to act as the "first leaves" and provide nutrients to the growing plant by photosynthesis. As the leaves mature and the plant grow, the cotyledons will eventually degenerate and detach from the hypocotyl. After the emergence of the first leaves, the plant will continue to mature for approximately six weeks. After this period, the plant will enter the vegetative stage and begin to flower.

7.2 Vegetative

The Rajmash plant shows four growth habits:-

a) Growth habit I -Determinate plants of rajmash may have 3 to 7 trifoliate leaves on the main stem before the terminal double raceme (as found in 'bush' or 'dwarf' cultivars), or maybe many noded with 7-15 (Middle American) or 15-25 (Andean) trifoliate leaves on the main stem (Debouck, 1991).

b) Growth habit II-Rajmash plants have an upright habit, with an erect stem and branches.

c) Growth habit III-Rajmash plants have a bush habit with weak and prostrate stem and numerous branches; having a short or long guide and with variable ability to climb.

d) Growth habit IV- Rajmash plants have climbing habit supported on a suitable plant, with a weak, long, and twisted stem and reduced branching.

7.3 Flowering

Time to flowering varies with cultivar, temperature, and photoperiod. Flowering is usually initiated 28-42 days after planting. Flowers of wild *P. vulgaris* are generally purple, pink or white (Gentry, 1969). The floral structure of *P. vulgaris* contributes to the high rate of self-pollination: anther dehiscence and stigma receptivity occur at the same time before the flower is fully open, and the anthers and stigma are positioned near one another at the time of anther dehiscence and stigma receptivity. Flowering in cultivars of growth habit I is concentrated over a very short period of time (usually 5-6 days), with drought or other stresses imposed at this time having a marked effect on yield. Indeterminate cultivars produce additional nodes after initial flowering, with flower formation thereby extended to 15-30 days. As many as two-thirds of all the flowers produced may abscise, and under temperature or water stress, young fruits and developing seeds may also abort. Abscission is greatest among flowers formed on the upper nodes and branches, and within a raceme is greatest among the later flowers to form (CIAT, 1975).

7.4 Podding

Seed-filling periods of the rajmash plant may extend from as few as 23 days in the case of the determinate cultivars to nearly 50 days in indeterminate and climbing varieties.

7.5 Harvesting

Physiological maturity is the stage beyond which no further increase in seed dry matter takes place. It may occur only 60-65 days after planting amongst those early varieties used in areas where the growing season is very

short, or extend to 200 days after planting amongst climbing varieties used in cooler upland elevations. The pods of rajmash should be harvested when they are fully developed, ripe and turn yellow. Generally, the overall crop gets ready to harvest in 120 to 130 days. As the pods start to become yellow and dry out, watering of the plant should be stopped. If it is not too humid and plenty of space is between plants, the beans may well dry on the plant. Moreover, leaves begin to yellow and most of them fall. Harvesting should be done as soon as possible to avoid breakage. The harvested plants should be kept in the sunlight for three to four days.

7.6 Threshing

Threshing is the act of removing the individual beans from the pod husk. In naturally propagating the plant it is left outdoors, the pods will continue to dry and the rajmash pods will drop into the soil. Rajmash pods must be harvested before the pods are fully open and the seeds are lost. Rajmash crops should be properly dried before threshing and should be done on a dry day, after a period of dry weather. There are two different ways to thresh rajmash. i) First method-The Tarp method of bean threshing and ii) Second method- The bag method of bean threshing. For both methods, allow the rajmash pods to turn brown and almost fully dry. As soon as some of the beans begin to crack open, pull them from the plants. The pods should be very "crispy" before separating the beans from the pods.

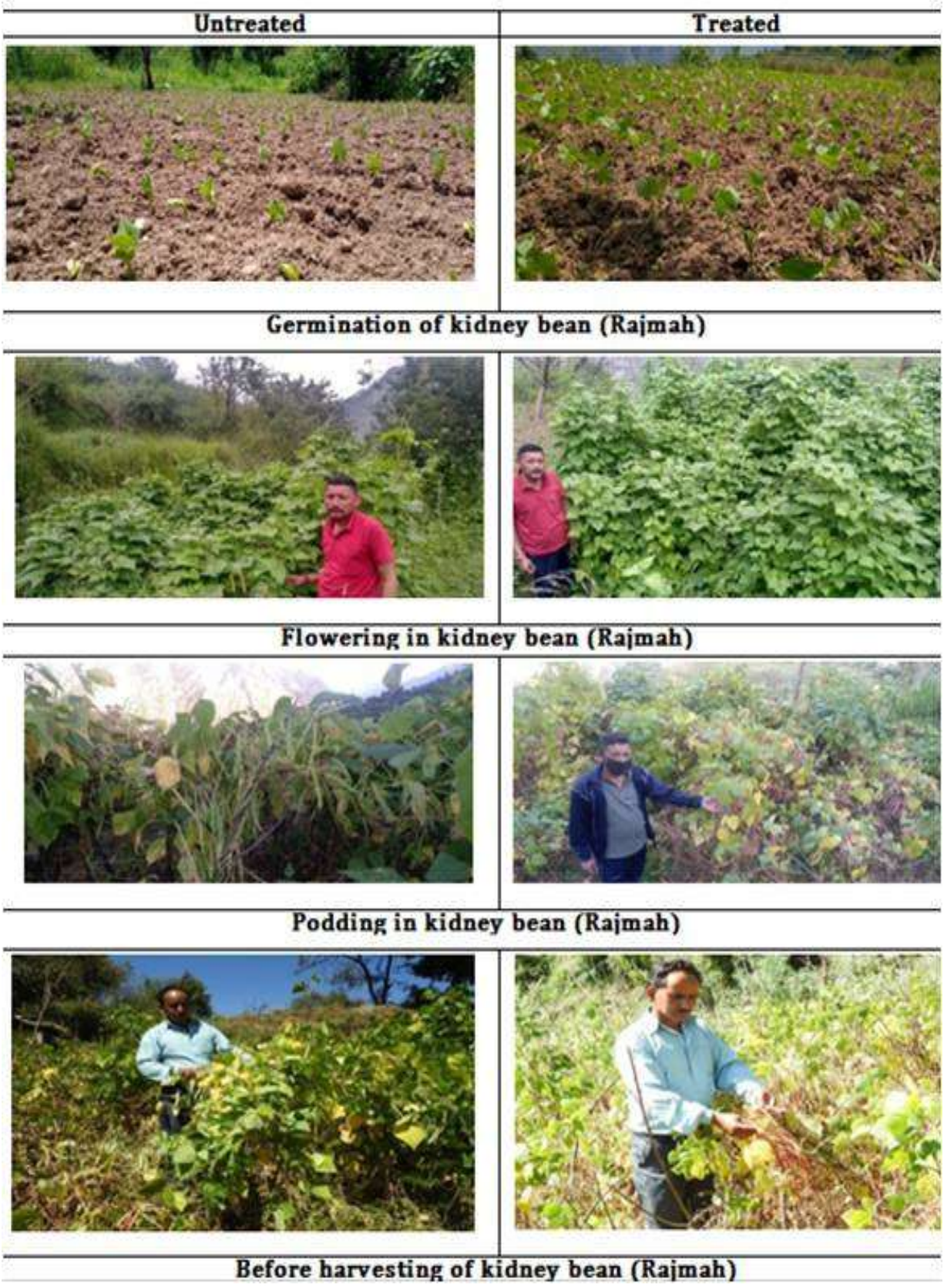
In the tarp method, when the bean pods are fully dry, spread a clean tarp out on a flat, stable surface (concrete platform). Empty all the bags full of bean pods on half of the tarp. The empty half of the tarp over the beans should be folded so that it is fully covered. Then pressure is to be made with feet or stick. The seedpods beneath the feet will crack open releasing the hard, dry seeds from their husks. Whereas in the bag method, a bag is used to thresh the beans instead of tarp. The dried pods are simply transferred from the paper bags filled with beans into the empty bag which is half filled. Then, these bags are tied pressing out as much air as possible before sealing it and pressurize it repeatedly onto a wall or hard surface to separate the beans from their shells. In hills, after removal of grain, it was again sun-dried for 3-4 days to bring their moisture content to 9-10% and stored for sale.

8. Disease management

Rajmash plant is affected by several bacterial, fungal, and viral diseases. However, most of rajmash plants can be prevented by selecting and planting disease-resistant varieties. Diseases and their management has been described below:

8.1 Common cultural practices

Cultural practices in pest management are methods of pest control consisting of regular farm operations in such a way that either destroys the pests or prevents them from causing economic loss. The most important advantage of cultural practices in pest management is that these practices make the environment less attractive and favourable to pests for their survival, dispersal, growth, and reproduction and promote the pest's natural controls. Cultural practices include cultural controls which mean that reduce pest establishment, reproduction,



Showing different growth stages of rajmash crop along with the impact of biofertilizers treatment (Treated with comparison to untreated)

Sun drying

Threshing

dispersal, and survival. For example, the preparation of nurseries or main fields free from pest infestation by removing plant debris, trimming of bunds, treating soil and deep summer ploughing which kills various stages of pests. Similarly proper selection and rotation of crops, sanitizing and solarizing the soil, choosing the best planting and harvest times, using resistant varieties and certified plants or by changing irrigation practices can reduce pest problems. Likewise irrigations at critical stages of rajmash cultivation should be provided and water stagnation conditions should be avoided since too much water can increase root diseases and weeds.

8.2 Common mechanical practices

Common mechanical practices in pest management means controlling the pests with physical methods or through mechanical devices such as knocking pests off of plants with a spray of water, using barriers and traps, mulching and treatments etc. On the other hand, mechanical practices include traps for pests, animals and insects, mulches for weed management, steam sterilization for soil disease management and barriers such as screens or fences to keep animals and insects out. Mechanical controls offer several advantages. They are more familiar to users, cheaper to produce, purchase, and replace, and have a longer life cycle. The importance of using the mechanical or physical method in controlling pests is that they kill a pest directly or eliminate from the surrounding environment. Common mechanical practices in pest management of rajmash cultivation include the following steps-

i. Eggs and larvae of leaf miners, gram pod borer, aphids, stem fly, and root knot nematode at the vegetative stage of rajmash should be collected and destroyed.
ii. Disease-infected and insect-infested plant parts should also be collected and destroyed.
iii. Yellow sticky traps for aphids and leaf miners at four-five traps/acre should be used.

iv. Light traps at one per acre should be used and operated between 6 pm and 10 pm.
v. Erecting bird perches at 20/acre encourages predatory birds such as the king crow, common mynah, etc.
vi. Bonfire during evening hours between 7-8 should be set up.

8.3 Common biological practices

Biological control is the most crucial element for pest and disease management using biological methods. Biological practices are the employment of live organisms to keep unwanted living organisms (pests) under control. For instance, enhancing parasitic activity by the augmentative release of natural enemies when larval parasitoids are observed. In the field, there are three main approaches fused for biological control:

- Conserving already existing natural enemies through ecological engineering
- Introducing new natural enemies and establishing a stable population (referred to as "classical biological control"), and Mass-rearing and periodic release, either on a seasonal basis or inductively (When releasing large numbers of natural enemies, the individuals released are expected to provide biological control). For example, *Amblydromalus limonicus* (Limonicus mite) is a predatory mite control thrips, a whitefly, while *Adalia bipunctata* (Ladybird beetls) is a predatory beetle which targets and eats aphids.

8.4 Stage-wise Integrated Pest Management

Rajmash known scientifically as *Phaseolus vulgaris*, are a major legume crop grown for their nutritious seeds. Like other agricultural product, Rajmash are also vulnerable to a variety of pests that can cause substantial harm if left unchecked. To protect rajmash crops from pests effectively stage-wise pest management measures must be implemented. Here is a brief overview of stage-wise pest management in kidney beans:

i. **Pre-Planting Stage:** Before planting kidney bean seeds, it is critical to examine the pest history of the field and conduct preventive measures. This includes testing the soil for nutritional deficiencies and pH levels, as well as ensuring appropriate drainage and eliminating any weed or crop residue that may harbour pests or diseases.
ii. **Planting Stage:** During the planting stage, it is advisable to use high-quality disease-free seeds. This aids in the prevention of diseases and pests from entering the crop. Furthermore, proper planting procedures, such as seed spacing and depth, can promote healthy plant growth and also reducing pest pressure.
iii. **Seedling Stage**: Kidney bean plants are subject to pests such as cutworms, aphids, and flea beetles during the seedling stage. Regular monitoring is essential for early detection of insect infestations. To protect young plants from insect damage, physical barriers such as row covers or nets might be used. If pest populations are high, a targeted insecticide application may be necessary.
iv. **Vegetative Stage:** As kidney bean plants enter the vegetative stage, pests like leafhoppers, thrips, and mites become more problematic. Integrated Pest Management (IPM) practices, which include a combination of cultural, biological, and chemical control approaches, should be implemented. This can

include practices like crop rotation, removing weed hosts, introducing beneficial insects, and judicious use of insecticides if necessary.

v. **Flowering and Pod Formation Stage:** Kidney beans are susceptible to pod borers such as bean fly and bean pod borer during flowering and pod formation. Proper field sanitation, such as removing infested pods and destroying crop residues, is essential to prevent the carryover of pests to subsequent seasons. If required, insecticide application should be timed correctly, considering the pest life cycle and avoiding harm to pollinators.

vi. **Harvesting and Post-Harvest Stages:** Pests such as bean weevils and storage pests can cause harm to stored kidney bean seeds during harvesting. Proper drying and storage practices, including cleaning and fumigation, can help to reduce bug losses.

Regular scouting and monitoring of pest populations are crucial at all phases for early detection and timely intervention. Farmers should keep up to date on the most recent research and suggestions for kidney bean pest management to use the most effective tactics while minimizing the impact on the environment and beneficial creatures.

Kidney bean producers can increase crop output and quality while reducing pest-related economic losses by implementing stage-wise pest management practices.

9. Marketing strategies for improving farmer income

Marketing strategy for rajmash selling is required to focus on market expansion for the current market and the establishment of new markets through product differentiation. There is a tremendous market opportunity for selling rajmash due to the high demand of rajmash in both urban and rural areas as well as in international markets. To get the best price for their produce, farmers must be aware of the best-selling possibilities of rajmash. Building a product's value and promoting it as a specialized product are crucial components of a marketing plan. The most important step is to raise awareness for the produce among customers and buyers. The following attributes can be highlighted in order to develop an appropriate strategy to reach the objective of doubling and improving the farmers' income:

I) Agricultural Marketing

Agricultural marketing involves all the activities involved in getting an agricultural product from the farm and their distribution to the consumer. Planning, arranging, directing, and handling agricultural products in order to satisfy farmers, middlemen, and consumers are all part of agriculture marketing services. An essential part of efficient marketing is delivering goods on time, according to consumer demand, and in the appropriate quantity and quality. The Indian government has created a brand-new website called “Agmarket” where prices for all crops, including rajmash, are pooled and regularly updated from different districts and metropolitan marketplaces. Farmers can use SMS and Kisan Call Centers (KCC) to get price information for their produce.

Table 1 Disease of rajmash their symptoms and control methods

Name	Disease symptoms	Control methods
1. **Rust (caused by *Uromyces appendiculatus*)**	All parts of the plant surface above the ground develop rust patches, often known as pustules. They are most prevalent on leaves, especially the underside. On stems, they are less common, and on pods, they are sporadic. The first signs are tiny, slightly elevated yellow pustules that eventually develop into prominent circles that are reddish brown in colour and encircled by a yellow halo.	Avoid continuous bean cropping or follow intercrop with cereals. Crop residues should be destroyed after harvesting. Resistant varieties of the plant should be grown. Use Mancozeb at the rate of 2.0g/liter water at the time of disease appearance.
2. **Anthracnose (Caused by *Colletotrichumlindemuthianum*)**	Any portion of the plant can develop anthracnose symptoms. The lesions are elongated and sunken on the stem. The fungus produces black, sunken lesions on the pods. These lesions can cause the immature pods to shrivel up because they penetrate deeply into the pods. Infected seeds turn from yellow to brown to black and occasionally the entire plant dies.	Healthy seeds should be used. Thiram (75% WS) should be used for seed treatment at 2.0g/kg seed. Spray of mancozeb at 0.25% or carbendazim 0.1% should be done at 8–10 day interval.
3. Angular leaf spot (caused by *Phaeoisariopsis griseola*)	All plant aerial parts, such as leaf, stem, petiole, and pods, exhibit the symptoms. It consists of small dark brown spots with angular edges that are frequently numerous and gives the foliage a checkerboard pattern. Generally, the spots on leaves are large in size and cause yellowing and necrosis which could lead to premature defoliation.	Healthy seeds should be used and practice crop rotation in affected areas. Thiram (75% WS), carbendazim (2.0 g/kg seed), or Trichodermaviride (4.0 g/kg seed) are treatments for seeds. At the first sign of symptoms, spray azoxystrobin at 0.1%, mancozeb at 0.25%, or carbendazim at 0.1%.
4. Bacterial blight (Caused by *Xanthomonasaxonopodis*pv. *phaseoli*)	Spots on leaves, which upon exposure with water become larger and necrotic, these spots may be surrounded by a zone of yellow discoloration, lesions merge and give the plant a burned appearance. Pods may have a round, depressed, reddish-brown lesion. Seeds in the pod remain discolored and sunken.	Use of resistant species. Avoid crop rotation for two to three years including legume. Intercropping beans and maize has been demonstrated to lessen the severity of common bacterial blight. To prevent the spread of pathogens using water, irrigate the basal portion of water or utilize the sprinkler method. Copper hydroxide application may be used if blight is seen on different parts of plants. Crop debris should be buried in the soil.
5.**Root rot (Caused by *Rhizoctoniasolani* and *Fusarium* sp.)**	Long, reddish-purple lesions on the root tissue and stems that turns black or dark grey. Deep lesions can result in stunted growth, wilting and defoliation of leaves and lead to plant death.	Always cultivate root rot resistant or tolerable varieties.Deeply plough bean debris after harvesting. Early seeding reduces disease, but losses during the rainy season are substantial. Grow beans in ridges or hills with thick soil. Field water should be properly drained. Thiram or carbendazim at 2.0 g/kg of seed or the bioagent *Trichoderma harzianum* at 10 g/kg of seed should be used to treat seeds.

6. Pod borer (*Helicoverpa armigera*)	The larva eats the seeds by boring circular holes in the pods. Larvae are frequently seen partially hanging outside the bored holes.	Growing marigolds at the sides of tomato fields encourage adult female moths to lay their eggs on the marigold flower, and act as a trap crop. It is advised to release 3–4 spray of *Trichogramma* sp. during flowering, each lasting 7–10 days (1 card/200 m^2) for destroying the moths eggs. Pheromone traps (Helilure®) installed at a rate of 12 per hectare attract and capture adult male moths, allowing for pest management. placing 15–20 bird perches per hectare to attract insectivorous birds. 5% NSKE (Neem Seed Kernel Extract) against early instar larvae. Spraying Bt 2g/L is advised for controlling larvae, and in extreme circumstances, spraying Spinosad 0.3ml/L or indoxacarb 1ml/L is advised.
7. Leaf miner (*Liriomyza* sp.)	It is a pest that feeds on a variety of crops. Small brown flies that are adults place their eggs on newly formed leaves. The grubs create the white serpentine lines or mines on the leaves by burrowing into the leaf and feeding on the inner tissues of the leaves. Leaf fall is a result of severe infestation.	Yellow sticky traps can be used to capture the adults. The early stages of an infestation allow for the removal and destruction of infested leaves. It is advised to use a 0.3 ml/L Difenthiuron spray.
8. Blister beetle (*Mylabrispustulata*, *M. phalerata)*	It is a pest of floral plants, okra, pigeon peas, and rajmash. It damages the environment by consuming flower buds and blooms. Feed occasionally on developing fruit and as well as pods.	It is advised to kill the pest by submerging the hand in the water while wearing gloves. Deltamethrin 1 ml/L spray may be advised for seed crops. It accumulates on bunds, thus evening spraying of bunds is a viable option.
9. Whiteflies (*Bemisia* sp.)	Whitefly is a polyphagous pest that affects practically all planted crops, especially under polyhouse circumstances. The developmental stages are passive. Adults are tiny, white, moth-like flies that can be seen sipping plant sap from the underside of leaves. It helps in the spread of plant diseases.	It is advised to use yellow sticky traps to attract in and capture adult flies. Coccinellids, in particular *Serangium* sp., eat grubs and flies for food. Acetamiprid or Pymetrozine 0.3 mL/L sprays are advised.
10. Thrips (*Thrips* sp., *Scirtothrips* sp., *Frankliniella* sp.)	The nymph and adults eat leaves and developing tips by scraping and swallowing the leaking sap. The damage results in classic boat-shaped leaves and silvery symptoms. Plants get severely stunted, and their yield decreases.	Adult thrips are attracted and captured in a yellow or blue sticky trap. Imidacloprid 0.3 mL/L spray is recommended.

11. Mites (*Polyphagotarsonemus latus, Tetranychus urticae*)	Tetranychus, a red mite, and Polyphagotarsonemus, a small green mite, both feed by sucking plant sap. They have typical inverted boat-shaped leaves. These mites cause crinkled leaves and elongated petioles.	The plant parasite mites are known to feed upon predatory mites and some coccinellids. It is suggested to apply a 0.3 or 1 ml/L dicofol or abamectin spray.
12. Cutworms (*Agrotis* sp.)	The crop is initially infested with cutworms, particularly during transplantation. By chopping off the stems of the seedlings, they feed less but do serious damage. They make cuts in the seedlings that look like they were made with a knife at the ground level. They primarily graze at night and hide during the day	Clean cultivation eliminates cutworm pests because they prefer to hide in grass or garbage. Farmyard manure contains eggs or larvae, so it is suggested to apply decomposed and dried FYM to seedlings, particularly in poly houses. Batain fruit extract (5%) can be used to keep the bugs away. For the management, profenophos 3 ml per liter of water should be sprayed.
13. Bihar hairy caterpillar (*Spilosoma obliqua*)	The leaves shelter the eggs laid by the moth which are a light brown colour in groups. Generally, the caterpillar infestation appears just after a rainstorm. The larvae in the first instar are yellow in colour and have warts and hairs. They feed massive numbers on the leaves. The infestation can be seen even from a distance, turning the leaves into a papery structure since they normally eat by leaving the epidermis intact.	Farmers can eliminate the egg mass or the gregarious larva in its early stages. Emamectin benzoate 0.3 g/L or is suggested in extreme situations. It is recommended to use 1 ml/L of indoxacarb on mature larvae.
14. Sucking bug (*Chauliops choprai*)	Small, silvery and black beetles were seen sucking the cell sap to feed on the leaves. Necrotic spots, which are characterized by tiny white spots are present throughout the infected leaves. These necrotic spots are caused by the piercing of leaves. The damage is frequently severe in regions with high plant densities or in shady areas.	Use nitrogenous fertilizer only in the appropriate amounts. In endemic areas, planting rajmash in shade may be avoided. Fruit extract from the batain tree at 5% is fairly useful. At a concentration of 1 g/L Cartap hydrochloride spray is recommended.

The standard eleven-digit toll-free number 1800-180-1551 is made available nationwide to the KCC.

ii) e-National Agriculture Market (e-NAM)

The e-National Agriculture Market (e-NAM) is a pan-Indian electronic trade facility that was inaugurated on April 14th, 2016, and totally sponsored by the Central Government and operated by the Small Farmers Agribusiness Consortium (SFAC). The National Agriculture Market (e-NAM) Portal provides access to all the information and services associated with the Agricultural Produce Marketing Committee (APMC) from one site. This is a form of direct marketing of products to the buyer's wholesalers in any region of the nation by removing intermediaries and marketing fees in the APMC mandi system. This changes the APMC mandi system structurally. Transaction can still take place between farmers and traders without transporting the produce to the mandi. The major goals of e-NAM are to eliminate information asymmetry in the market, improve real-time price awareness, and promote uniformity in agricultural marketing. The farmer now has more options when he brings his produce to the mandi for sale due to e-NAM. Farmers can download the National Agriculture Market smartphone app by visiting the Google Play store. Farmers can email nam@sfac.in to contact the SFAC, New Delhi. Farmers can learn more about the programme on this website, www.enam.gov.in. or by contacting toll free number 1800 270 0224.

iii) Farmer Producer Organization (FPO)

The Farmers Producers Organization (FPO) is a group of farmer-producers that supports small farmers by offering comprehensive services that almost entirely cover all aspects of agriculture. Support for the promotion of FPOs is provided by the Small Farmers Agribusiness Consortium (SFAC). According to the regulations of the Ministry of Agriculture and Farmers Welfare, an FPO can be formed by any group of farmers with a minimum of 11 members. The FPOs has negotiating strength and are able to sell to prospective customers anywhere in the nation with better margins that directly benefit the producer's members according to the share. FPO's have free or paid access to technical support from Krishi Vigyan Kendra (KVK), the state agricultural department, private extension services, etc. FPO's can be connected to the e-NAM digital marketing platform to eliminate middlemen. They can improve their marketing through quality controls, value addition, standard packaging, branding, and competitive pricing to draw customers in order to increase the farmer’s share in the consumers rupees and thereby improves the farmers' livelihood in India (Mukherjee et al., 2019). Farmers can learn more by contacting the director of the relevant division or the Small Farmer Agri-business Consortium at their Email id i.e. sfac@nic.in.

iv) Agricultural price policy

The Indian government intervenes in the market to defend farmers against a sharp decline in farm prices through its agricultural price strategy. In order to guarantee support prices for farmers and reasonable prices for

consumers, the Agriculture Price Policy's Minimum Support Price (MSP) is a crucial element. The Indian government pays farmers a set sum known as the Minimum Support Price (MSP). It is determined before the sowing season in order to encourage increased investment and production of agricultural goods. The Government of India releases the minimum support prices at the beginning of the planting season for particular crops based on the recommendations of the Commission for Agricultural Costs. Farmers have a safety net in the form of MSP, which ensures a minimum price for their produce. Farmers can obtain the MSP for rajmash through the National Agricultural Cooperative Marketing Federation of India Ltd. (NAFED) and the Small Farmers Agri Consortium.

v) Contract farming

Contract farming refers to an agreement between farmers and processing or marketing firms for the production and supply of agricultural products under forwarding agreements at predetermined prices. Contract farming is a system that enables the primary producer (farmer) to supply land-based produce under a contract in advance. Contract farming is the key component in which the buyer/contractor provides the farmer with the necessary material inputs and technical advice regarding crop production. The primary commitment under such a contract is to deliver agricultural products of a particular kind, quality, and quantity at a given time to the contracting party. Contract farmers frequently have access to credit of some sort to pay for the production inputs. Additionally, it ensures higher-quality produce, cash or in-kind financial assistance, and technical assistance for farmers. Farmers have now a secured market due to contract farming, and opportunity for increasing their capacity to produce.

vi) Direct marketing

Direct marketing enables farmers to take the responsibility and benefits of providing top-quality agri-food products to consumers through a variety of marketing techniques. Farmers use direct marketing to approach potential customers and seek for their business where farmers producers get the maximum share in consumers rupee paid at the market. The variables that adversely affect farmer direct marketing are lack of market information, competition, insufficient cold storage, and price volatility. Examples of direct marketing include subscription farms and community-supported agriculture (CSA), in which customers purchase a "share" from the farm at the start of a growing cycle. Local markets give small farmers a chance to sell their products. They receive a consistent supply of naturally grown and harvested produce in return. Farmers can effectively contact their target population through direct marketing without the involvement of a mediator thus helping to increase farmer's incomes by reducing the number of middlemen in the marketing process. Direct marketing of food products to consumers is a feasible way to increase the value of agricultural produce. Successful initiatives like Apni Mandi in Punjab, Uzhavar Sandai in Tamil Nadu, Rythu Markets in Andhra Pradesh, etc., should also be encouraged across the country. This type of market allows farmers and producers to sell their products directly

to customers in a market yard with the minimum infrastructure. It is an effort to cut out intermediaries so that growers would profit from higher prices and consumers would benefit from lower prices.

Post-harvest management

Post-harvest management is a strategy for controlling, transporting, and storing agricultural products after harvesting. The primary goals of post-harvest handling are to stop rotting by keeping the food cool, reducing moisture loss, slower changing unfavourable chemical reactions, and minimizing physical damage like injuries. Value addition refers to the process of realizing a high price for the same volume of a primary commodity by processing, packing, enhancing the quality, or using other comparable methods. One benefit of value-added crops is better nutrition for mothers and children which might boost farmer income and open up new markets. Bean products made by food processing, such as frozen, extruded, microwavable, and dried bean products, bean crumbles, flours, flakes, and quick-cooking beans, are more expensive than the original product in the market by adding phosphate salts. Thus, in order to minimize post-harvest losses and maximize earnings, food processing must be used extensively.

10. Conclusion and recommendation

Developing countries are very much expected to suffer with massive food requirement to meet the ever growing food demand with exponential population increase. Therefore, the production of all crops must be increased to overcome such big challenges. Legumes such as rajmash are the primary source of proteins and minerals and have a significant role in human diets. The Central Himalayan belt of Uttarakhand is a massive rajmash grower but due to various biotic and abiotic factors, poor knowledge of farmers and conventional agriculture practices the yield and nutrients of rajmash is being depleting. Apart from natural factors, scientific and precised method for rajmash cultivation must be disseminated among the farmers through training and awareness program, and extension activities. It includes knowledge about the varieties of crop cultivating by farmers, their cultivation, and management strategies such as identification of feasible climatic conditions, soil preparation, and nutrient balance through organic fertilizers application (such as potential biofertilizers, compost, and manure) weed and pest control. This knowledge can improve the productivity as well as their socioeconomic status of farmers. Rajmash farming of Himalayan region is completely organic, which is also a reason for comparative low productivity, therefore it is recommended that government can develop a organic corridor in the state and provide possible subsidies to the rajmash growers of Himalayan region to maintain the organic status of the state. This would be greatly helpful to attract the farmers for organic farming and will be stepping stone towards the complete transformation of the state into organic state. Moreover, various government initiatives for livelihood enhancement and product selling opportunities through e-NAM, Mandi, Apni mandi, along with NGO formation such as FPOs and marketing strategies will be helpful in efficient selling of crop produce. Therefore, accessible knowledge of the crop cultivation and selling opportunities in the form of such policy

document and its sincere implementation from the farmer's end would results in the higher productivity and upliftment of socioeconomic status of hilly farmers.

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