PRODUCTION TECHNOLOGY FOR MOTH BEAN IN INDIA

Compiled by
D. Kumar
All India Coordinated Research Project on Arid Legumes

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INDIAN COUNCIL OF AGRICULTURAL RESEARCH
Central Arid Zone Research Institute, JODHPUR – 342 003

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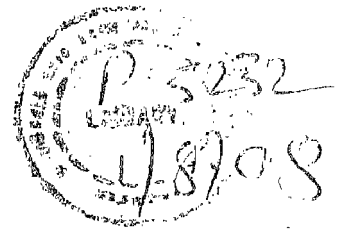

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Printed : January, 2002

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Assistant Director General (O & P)
I.C.A.R., Krishi Bhawan
New Delhi

Published : Dr. Pratap Narain
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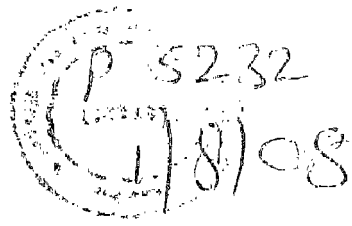
Jodhpur – 342 003
Ph. : 0291-2740584
Fax : 0291-2740706

Citation : Kumar, D. (2002) :
Production Technology for Moth bean in India

Printed at : Indian Turisum Publication
743, Opp. Nehru Park, Jodhpur – 342 001
Ph. 0291-2641788, 2641023



Production Technology for Moth bean in India

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FOREWORD

Moth bean is reckoned with adaptation to moisture stress and environmental hotilities of arid zone. Hence, cultivation of these arid legumes is traditionally concentrated in Western zone of Rajasthan. It occupies 86.0% acreage of the country and contributes almost 82.0% towards national production. It is a cheap source of vegetable proteins to the rural masses and its green leaves are sometime used as a vegetable. During extreme drought situations, this is the only crop, which may be cultivated for grain and fooder with minimum, water, tillage and other agronomic inputs. Moth bean is regarded as most popular corop at the farmer's behest. It is an essential component of cropping system for sand dune, plain lands and degraded lands. The productivity of moth bean is about 254 kg ha^{-1}, which is serious concern to all. Suitable technologies and their adoption at large scale may enhance production remarkably.

A comprehensive and concise technology bulletin on moth bean will act a stitch in time for enhancing production of this valuable legume in arid zone.

I am happy, that this bulletin "Production Technology for Moth bean in India" is a timely effort in a drought year like this one. The contributors to the bulletin as well as the compilers deserve compliments.

It is hoped that the bulletin would be handy and useful to all concerned with moth bean production in India.

Date : 31-1-2003

Place : Jodhpur

(Pratap Narain)

Director CAZRI, Jodhpur

PREFACE

Moth bean is the principal food legume for livlihood of arid farmers, who have been solely depending on agriculture under worst to worst soil-water-climate- input compendium. In such complex situations of extremely low, delayed or early breakdown of monsoonic rains, texturally poor and nutritionally deficient undulating lands, with little assurance of inputs and after care, moth bean becomes immediate and the lasting choice of the farmers for themselves, their livestock and for the health of the soil. This crop, therefore, deserves pampering with technological back-up for horizontal expansion to the traditional as well as newer areas and uplifting the productivity *per se*. The technological back-up comprising full package of pure and improved seeds, its timely availability, crop husbandry components, plant protection umbrella and human and industrial consumptions are of immediate concern. The same becomes all the more important because, technological back-up may sometimes be sophisticated, requiring educative orientation, being location and need specific, but the intended users are uneducated, unaffordable, unapproachable and traditionals-sticking rural masses. Thus, technologies whatsoever available, may require specific refinements in respect of each components of the packages, in view of their acceptability and implimentability due to multitudes of the devastating problems from one step to next. Thus, a very sensitive bridge is to be framed out between implementing and the accepting agencies. Having these issues in mind, package of practices on moth bean have been calibrated and neated in the form of present compilation. This compilation consists of all smaller to larger components of the technology in simplified, convenient and comprehensive form.

It is hoped that the compilation would help increased area and production of moth bean and its expansion to newers and non-traditional arid and semi-arid regions of India.

(D.Kumar)

ACKNOWLEDGMENTS

It yields immense pleasure in recording continued inspiration, guidance, and moral-boost attitude extended by Dr. M. Rai, Secretary, DARE and Director General, ICAR, New Delhi, in effective implimentation of AICRP on Arid Legumes and help in bringing out this bulletin. Dr. Rai's never lasting positive and optimistic attitude is acknowledged in most valuable words.

Dr. Pratap Narian, Director of this Institute, is thanked for constant vigilant directions in execution of the project and according administrative approval for publication of this bulletin.

I profoundly thank Dr. N.B. Singh, A.D.G. (Oilseeds & Pulses) ICAR, New Delhi, who has proved a real source of inspiration and has been providing never ending support in bringing out books and bulletins in this project. It is he, on whose inspiration, this bulletin has taken shape.

All the scientific, technical and supporting staff members of this project engaged is moth bean research across the regions and institutions are heartly rembered and their contributions in one way or other are recorded with great honour. This bulletin is the extract and abstract of their long and continued research efforts.

The staff members and researchers in PC Unit, CAZRI, Jodhpur like, Mr. P.S. Bhati; Drs. Manju Singh and Neetu Rathore; Miss Seema Gaur; Aarti Shekhawat, Mr. Bhanwar Singh and Mr. Ummaid Singh are thanked for helping me at the needed hour. Mr. Bisan Lal, Sr. Clerk, Central Store, CAZRI, is also thanked for help in financial estimates and getting this bulletin printed.

Jodhpur **(D. Kumar)**

CONTENTS

INTRODUCTION

Moth bean (*Vigna aconitifolia* (Jacq.) Marechal) known by several vernacular names (*Math, Kheri, Madike, Bhioni, Kunkuma, Matki* etc.) in different linguistic zones of India, indicates its wide social acceptance and geographic adaptation. It is important crop of arid and semi-arid regions, especially of the Northern-Western desertic regions of Indo-Pak sub-continent. Ecologically, it is an annual legume of dry and warm habitats and is characterized as the most drought hardy annual legume in arid regions. Moth bean with deep and fast penetrating root system, can survive upto 30-40 days in open fields, experiencing fast depletion of soil moisture, in concomitant with atmospheric temperature peaking to more than 35°C. These adaptive features emboded in moth bean against harsher and unhospital growing situations for unspecified intervals, have led this crop to be recognized as the arid legume. Not only adaptive features but broad canopy, winy and semi-trailing growth habits also prove useful in keeping the soil moist and lowering the soil temperature besides, help reducing the soil erosion. Thus, as a temporary *in situ* shelter belt, it may be treated as biological means for soil and soil moisture conservation. These multi-adaptive and adjusting features have scaled moth bean as the only alternative annual crop of the sand dunes, requiring no inputs and negligible agronomic aftercare. The crop is an essential component or sub-segment of cropping systems, prevalent and common, in arid zone like, agri-horticulture, silvo-pastoral, agro-forestry, mix-cropping, intercropping, sole cropping etc. This crop is therefore, a part of all systems of texturally common poor lands representing the holding of common men, characterized with limited physical and financial resources.

This crop does not claim to be a national pulse because its contribution in terms of area and production is to the tune of 5.9 and 1.6%, respectively. It is however, the most important pulse in arid zone perspective. Moth bean plants generally grow 15-40 cm tall, having short internodes. Primary branches being as large as 1.5 m, trail horizontally on the ground giving mating type look. Deep lobed leaflets can easily distinguish this species from other common species of *Vigna* group. Flowers are papilionaceous. Flowers are 2-6 cm long, pods are yellow brown, bearing 4-10 seeds each. The distinguishing features of moth bean are deeply lobed leaflets (3-5 in number), pods appear to be nearly glabrous and stipules are small.

Moth bean is a source of food, fodder, feed, green manuring and used as pasture hence, serves as a multi-purpose crop. Green pods are delicious source of vegetables. Being pulse, it is a cheap source of vegetable protein for balancing the nutritional deficiency, most commonly occurring on less productive soils, on which financially less equipped, great

chunk of people have been depending for their livelihood. Moth bean is known for higher proportion of albumin and glutamin fractions of protein. It is also a good source of lysine and leucine amino acids. Dry seeds of moth bean are used for preparation of a number of delicious confectionary items (*papad, mangori, mogar, bhujia-namkins*), which are commonly used as daily snacks. These industries are coming-up in a big way, exporting such commercial edible products and generating employment for agro-based industries.

Besides, low productivity, moth bean is also known for plant type of primitive nature, conferring its evolution for survival but not for productivity gains. Thus, alterations in plant habits, i.e., early partitioning, early maturity and semi-erect to erect growth habits may be preferred over the traditional ones. Such plant types besides, boosting yield productions, will also attract this crop to newer and non-traditional areas. Technology on resistance potential to YMV and Bacterial leaf spot disease also need addressed and consideration for moth bean yield proliferation at the cultivar's level. Insect pests particularly, Jassids, white flies, pulse beetle, white grubs and storage pests deserve special management strategies so that yield losses due to the same could be brought to the minimum, at the intended growers levels.

Moth bean has been a neglected crop from the evolution view point hence, it is the marginal and secondary choice of the farmers. Furthermore, research efforts, wealth of literature are also scarce, scanty and unsystematically available in respect of this legume.

In view to raise the status of this legume from subsitence and secondary choice to a major crop choice by the substitution and replacement for other crops in harsh climatic zones and extension to newer and non-traditional zones, information on its package of practices have to be compiled, simplified and made available to the grass root growers, workers, consumers and those involved in its improvement. Package of practices, extractable from the continued researches being carried out at the research stations and institutions under controlled conditions are scarce can, however, be made available to the farmers. The present compilation is aimed in this same direction and addressed to the related problems.

AREA PRODUCTION AND PRODUCTIVITY

Moth bean an important member of *Vigna* group is recognised for remarkable adaptation in drought prone areas subjected to a series of environmental vagaries and ecological constraints. These abilities have established its concentration specially in Northern-Western desertic regions of Indo-Pak subcontinent. Besides, larger areas in India, moth bean is also sporadically grown for different purposes in dry habitats of Burma, Srilanka, Malaysia, South China and South-Western USA. In USA it is grown as pasture, fodder and green manure crop. Rajasthan being major moth bean growing state contributes almost 86% area of the country. The crop is also grown in other states also, like Gujarat, Haryana and Maharashtra, whereas its area is very low and insignificant in States of Punjab, Jammu and Kashmir, Madhya Pradesh and Uttar Pradesh. Water requirement of moth bean is very low, for instance on an average basis ET of this crop during emergence and early growth is estimated to be around 1.8-2.2 mm day^{-1}, whereas at flowering and pod formation stages the same is almost 4.8 mm day^{-1}.

During the period of five years (1990- 1994) kharif pulses in Rajasthan were grown in 37.23 lakh ha, with production of 8.45 lakh ton and productivity of 226 kg ha^{-1}; the corresponding figures for moth bean were : 12.78, 2.70 and 211. It is however, significant to mention that moth bean alone shares almost 34.32% area and 32.00% production of total kharif pulses in this state. However, moth bean may not be rated as a national pulse, for instance, its national contribution to pulses is hardly 5.9 in area and 1.6% in production; on the contrary, it appears to be a major pulse, as far the hot and dry regions of India are concerned.

At the country level, area and production of moth bean have been fluctuating due probably to rainfall intensity, its distribution and shifting and substitution of moth bean to more assured and remunerative crops. However, area, production and productivity of moth bean at the country level appear to have been settled to 13.52 lakh ha, 2.41 lakh ton and

215.26 kg ha^{-1}, respectively. (Table 1)

Table 1 : Area, production and productivity of moth bean in Rajasthan during past 20 years

Year	Area (lakh ha)	Production (lakh ton)	Productivity (kg ha^{-1})
1981	12.62	1.46	116
1982	12.67	1.43	113
1983	12.35	3.14	254
1984	12.20	1.91	157
1985	12.46	0.46	37
1986	11.53	0.42	36
1987	12.33	0.07	06
1988	11.15	3.83	343
1989	12.07	2.40	199
1990	13.35	4.05	303
1991	11.45	1.14	100
1992	12.80	3.51	274
1993	13.36	1.50	112
1994	12.91	3.31	256
1995	12.92	1.54	119
1996	12.20	3.10	254
1997	11.23	2.99	266
1998	8.78	1.04	118
1999	7.71	0.29	39
2000	9.61	1.38	144

Among the states, Rajasthan occupying 11.55 lakh ha, contributes 85% to the total area of moth bean in India, whereas, production contribution of this state being almost 78.4%. Thus, fluctuations in area and production of moth bean in Rajasthan would be a deciding factor for its fate at the country level. Maharashtra and Gujarat (1.25 and 0.60 lakh ha, respectively) are the next important states to Rajasthan as far the area is concerned. The contribution of other states is however, negligible. For instance, J&K (7.91 thousand ha), UP (1.51 thousand ha), Punjab (1.05 thousand ha) and Haryana, HP and WB are contributing dismally low. However, productivity of moth bean is maximum in States of Jammu and Kashmir and West Bengal (Ca 1000 kg ha^{-1}), followed by 552.3 kg ha^{-1} in Punjab (Table 2).

Table 2: Area, Production and Productivity of moth bean in different states of India (1984-85 to 1993-94)

States	Area		Production		Productivity	
	(000 ha)	Per cent of total area of the country	(000 t)	Per cent of the total production of the country	(kg ha^{-1})	Per cent increase/ decrease over the national value
Rajasthan	1155.43	85.39	228.37	78.41	197.77	-8.12
Maharashtra	125.43	9.27	37.16	12.75	296.26	+37.62
Gujarat	60.34	4.45	15.94	5.47	264.17	+22.72
J & K	7.91	0.58	8.30	2.84	1049.30	+387.45
UP	1.51	0.11	0.43	0.14	284.77	+32.29
Punjab	1.05	0.07	0.58	0.19	552.38	+156.61
Haryana	0.86	0.06	0.27	0.09	313.95	+45.84
HP	0.36	0.02	0.10	0.03	277.77	+29.03
WB	0.10	–	0.10	0.03	1000.00	+364.55
Total	**1352.99**	–	**291.25**	–	**215.26**	–

The most intriguing feature of moth bean is that Rajasthan with 86% of country's acreage the state is characterized with lowest productivity (197.7 kg ha^{-1}). Thus, production of moth bean in India could be enhanced either by increasing productivity in Rajasthan or by horizontal expansion of this crop to West Bengal, Jammu and Kashmir, Punjab and Maharashtra states having more than one lakh ha area with modest productivity.

As far the main moth bean growing state Rajasthan is concerned, the compendium figures (1988-1989 to 1996-97) indicate that the same is largely grown in 10 districts. Churu ranks first (334260 ha) in area, followed by Bikaner (262813 ha), Nagaur (191119 ha), Jodhpur (172384 ha), Barmer (148524 ha), Sriganganagar (30757 ha), Sikar (27614 ha), Jhunjhunu (20886 ha), Jalore (15652 ha) and Jaipur (14050 ha). In terms of production Churu (80306 t), Nagaur (44461 t), Jodhpur (41085 t), Bikaner (38497 t), Barmer (27688 t) were the important districts (Table 3). Not only the area and production but the productivity figures also considerably vary in important moth bean growing districts of Rajasthan . For instance, the same ranged from as maximum as 510 kg ha^{-1} (Sriganganagar) to lowest by 150 kg ha^{-1} (Bikaner) districts. Thus, there was no proximity among the districts as far area and productivity are concerned. Churu, Bikaner, Nagaur and Jodhpur districts having maximum area, were characterized with poor productivity. Thus, moth bean yield in Rajasthan could be raised by increased area in Sriganganagar and Sikar districts or by increasing productivity *per se* in Churu, Bikaner, Jodhpur and Nagaur districts (Table 3).

Table 3: Area, production and productivity figures of moth bean concerning ten important districts of Rajasthan.

Districts	Area (ha)	Production (t)	Productivity ($kg\text{-}ha^{-1}$)
Barmer	148524.33	27688.67	190.00
Bikaner	262813.89	38497.66	150.00
Churu	334260.89	80306.00	240.00
Sriganganagar	30757.56	15607.44	510.00
Jaipur	14050.11	4003.56	285.00
Jalore	15652.44	2728.00	170.00
Jhunjhunu	20886.89	4657.60	220.00
Jodhpur	172384.44	41085.11	240.00
Nagaur	191119.44	44461.22	230.00
Sikar	27614.00	8466.00	310.00
Total	**1218063.99**	**267500.28**	**220.00**
State Total	**1238164.58**	**271300.78**	**219.12**

Source: Directorate of Statistics and Economics, Government of Rajasthan, Jaipur and Revenue Department, Ajmer

IMPROVED VARIETIES

Inspite of great potential of this crop, as a source of food, fodder, feed and many confectionary items; having very high level of drought tolerance capability and showing adaptation to texturally poor soils, characterized with deficiency in nutrients availability, genetic improvement has however, remained at a low ebb. The number of improved varieties in relation to their importance and the vast area occupied to the tune of almost 13.50 lakh ha, are dismally low which do not cater the rising demands of pure and high quality seeds of this crop. The crop shows poor response to applied nitrogenous fertilizers and may not respond to high rainfall situations, hence role of improved varieties for specific rainfall pattern becomes quite crucial. Improved variety, therefore, becomes initial and the ultimate choice of inputs. Traditional varieties developed as germplasm from the natural habitats, were spreading types covering ground as mat, tended to grow slowly and matured in 100-120 days. These varieties (Type-1, Type-3, MG-1, Baleswar-12 etc.) were basically or predominantly fodder types having hardly 200-300 kg ha^{-1} of grain yield, in optimum conditions.

Such varieties as a rule generally suffered from the terminal drought and Yellow Mosaic Virus (YMV). Consequently, these varieties have virtually wiped out from the cultivation map of this crop.

The continued, sincere and delibrate efforts on genetic improvement of this crop led the development of varieties whose maturity period was curtailed to 75-90 days against those maturing in 90-100 days. These varieties (Jadia, Jawala, IPCMO-912, CAZRI Moth-1) were capable to yield better and withstood and braved the scorching heat and depleting soil moisture deficiencies (Plate 1). Such varieties were more suited to higher rainfall (250-350 mm) with its fair distribution (Table 4).

Following the release of RMO-40 in 1994, a new beginning of moth bean improvement took place. A series of varieties like RMO-257, RMO-225, RMO-435 and FMM-96 were released (Table 4). All these varieties belonged to early maturity group (60-67 days), depicted totally altered plant types being semi-erect to erect type, having synchronous maturity. These varieties due to short growing seasons successfully could evade drought

problems and escaped devastating diseases like (Yellow Mosaic Virus) and *Cercospora* leaf spot. Such varieties are however more suited to low rainfall (200-250 mm) and short growing season (Plates 2, 3). Thus, new tailored varieties of this group have high potential to yield (6-8 q ha^{-1}) and have increased harvest index upto 35%. Important features of some of available moth bean varieties are given below.

Table 4: Important old and new varieties of moth bean

Variety	Year of release	Maturity (days)	Grain yield (kg ha^{-1})	Adaptation	Salient features
A. Late Maturity Group					
Type-1	1967	120-130	200-300	UP situations	Brownish red seeds, with medium size, average forage yield 10-14 q ha^{-1}, basically forage type.
Type-3	-	120-125	350-375	Punjab and Haryana states	Forage type, 22-25 q ha^{-1} green forage, narrow lobed leaves, canopy radiates outwards and trails horizontally.
MG-1	-	110-115	350-450	Gujarat situations	Highly susceptible to YMV, plants are taller (45-55 cm) harvest index is low (10-12%)
Baleshwar-12	-	110-115	400-475	Gujarat situations	Highly susceptible to YMV, plants are taller, green fodder yield 15-17 q ha^{-1}, seeds are brown and medium sized (100-gram wt. 2.2 g), seed protein 23-25%, harvest index around 10.0%.

B. Medium Maturity Group					
Jadia	1980	85-90	450-500	All moth growing areas of India	Spreading growth habit, seeds are dark brown, medium bold (100-seed wt. 2.5-2.5g), susceptible to YMV, green fodder yield 10-12q ha^{-1}, HI 15-20%
Jawala	1985	80-90	500-550	All moth growing areas of India	Resistant to YMV, average fodder yield 17-18q ha^{-1}, HI 25-28%
Maru Moth	1989	80-85	500-550	Whole Rajasthan planting situations	Semi-spreading type, less affected by *Cercospora* leaf spot disease, suited for inter-cropping.
IPCMO-800	1989	80-85	450-500	Western Rajasthan	Spreading type, leaves are broad and deeply lobed, seed protein 22-24%, harvest index 20-25 %.
IPCMO-912	1994	75-85	400-500	Semi-arid regions of Rajasthan	Showing field tolerance to YMV and Bacterial blight, narrow leaflets.
CAZRI Moth-1	1999	72-75	500-650	Rainfed conditions of whole country	Semi-erect type, profuse bearing, seed protein 25-26%, showing field resistance to YMV.
C. Early Maturity Group					
RMO-40	1994	62-65	600-800	Arid situations of the country	Early maturity, erect synchronous growth habit, can escape drought and YMV infection, suited for close spacing, HI 30-32%, short stature.

RMO-257	1997	64-66	600-800	Arid and semi-arid tracts of India	Semi-erect growth habit, gives 18-20 q fodder yield ha^{-1}, bears 3-6 branches/plant, less YMV infection.
FMM-96	1997	58-60	500-700	Drought prone low rainfall zones	Extra early variety, short statured, erect growth habit synchronous maturity.
RMO-225	1999	62-65	600-700	Rainfed situations of arid and semi-arid regions	Semi-erect type, grain color light brown, escapes drought and YMV infection, fodder yield 17-20 q ha^{-1}.
RMO-435	2001	64-67	600-700	Dry and low rainfall zones of the country	Escapes drought, has resistance to YMV in field conditions, semi-spreading growth habit, may yield 10-12% higher over RMO-257. Leaves are broad with dark green color.

AGRONOMY

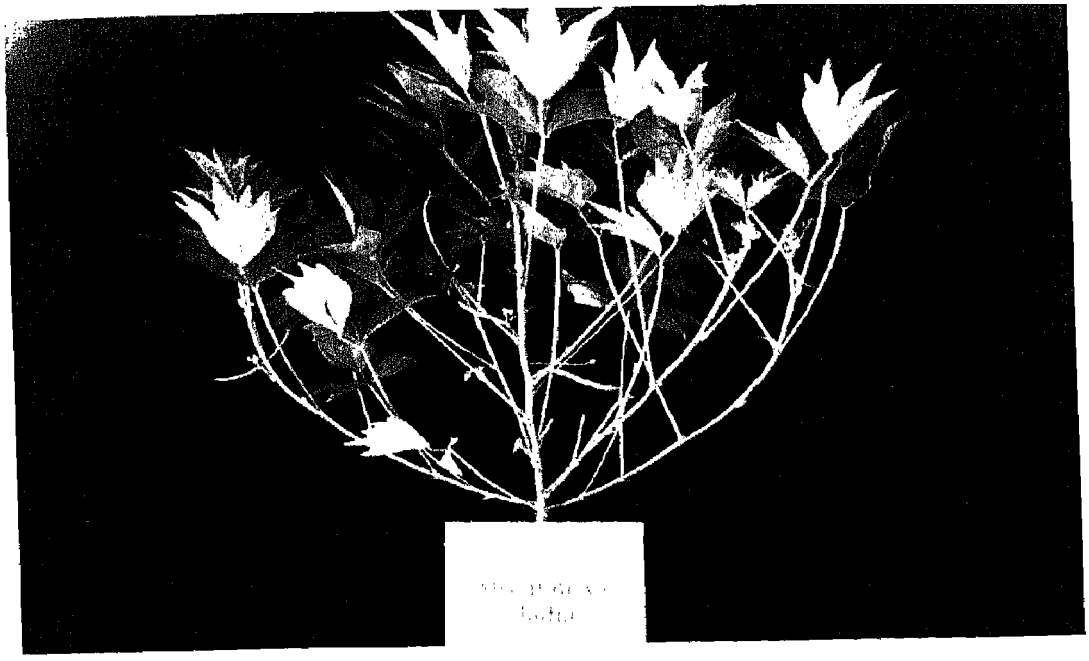
Management is important strategy for realization of enhanced productivity of legumes, grown with resource constraint situations, particularly on the neglected soils with poor productivity. Thus, under fixed and limited resources on the lands being cultivated by ill equipped and financially ridden arid farmers, acceleration in production of moth bean being less responsive to agronomic inputs is a big challenge. Thus, calibrated priority of the inputs and thoughtful implementable technologies, as a package and not single input, characteristically being simple, economic, lasting and convenient would be desired for such situations, which have hardly experienced any desired extension activity. Thus, technological agronomic inputs showing indelible impacts due to fast productive results may find places and figures amongst the unskilled and uneducated arid peasantry masses. It is all the more important, for the concerned rural masses have exclusively given up their tilt and inclination towards adoption of technologies other than those they have been practicing and inheriting from centuries. Thus, shift in their mind set is a big challenge. However, following aspects of crop production may bring some changes towards adoption.

Soil:

Moth bean doesn't require the soil conditions other than in which it is generally grown. In other words, moth bean can be successfully cultivated on well drained sandy plains and sand dunes with poor organic matters and poor fertility in Northern- Western arid regions of India.

Soil Preparation:

Moth bean is cultivated as sole, mix and intercrop on plain lands and sand dunes. For intercropping with bajra, soil may be prepared keeping in view bajra cultivation, which requires a mould board ploughing following a cross harrowing. Soil may be prepared so that soil moisture is conserved and weeds are completely removed out. On light soils and on sand dunes, crop may be sown immediately after rains, so as to lessen the soil moisture losses.



Old, traditional variety with less yield: Jadia

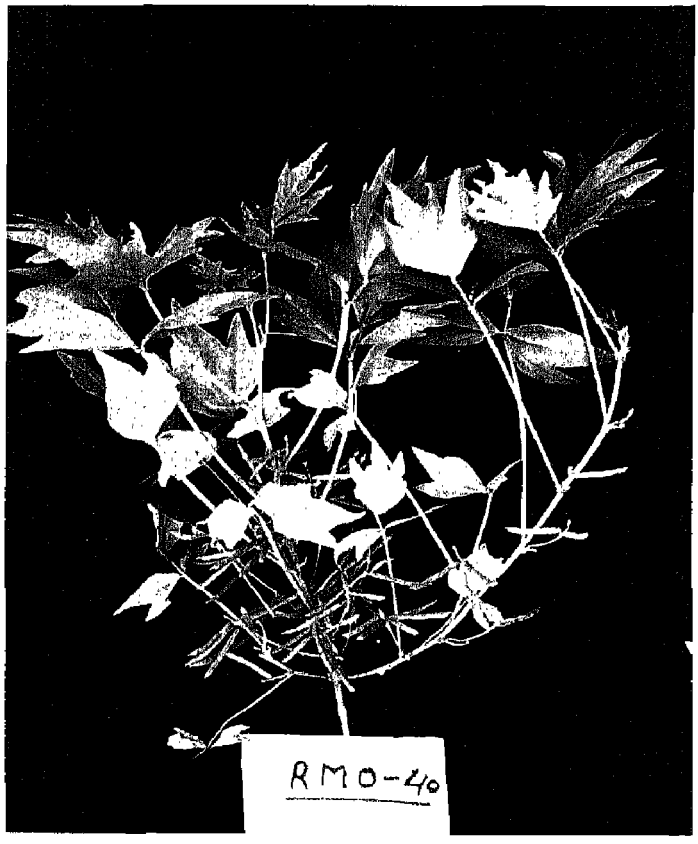
Semi-erect, highly drought tolerant variety resistant to YMV: CAZRI Moth-1

Plate - 1

Latest, high yielding variety with high grain protein: RMO-435

An early, semi-erect variety improved in yield and straw: RMO-257

Plate - 2



An erect, early high yielding variety: RMO-40

An early, high yielding variety: RMO-225

Plate - 3

Extra ploughings (more than one or two) before sowing may not be practised for avoiding loss of the upper surface of the soils due to high wind velocity.

Seed Rate and Sowing Methods:

Moth bean is sown as sole, inter-crop and mix-crop. It is also raised for grain and fodder purpose, as well. The varieties with profuse canopy and erect growth type are also available hence, seed rate may be accordingly decided keeping in view of crop requirements.

The crop being sown as sole for grain purposes in optimum sowing time, seed rate @8-10 kg ha^{-1} may be used. For fodder purpose, seed quantity at a rate of 20-22 kg ha^{-1} may be used. For mixed cropping with bajra, til, guar etc., moth bean may be sown @ 2-5 kg ha^{-1}. Seed proportion of moth bean, as a component of mix-cropping, may be raised on delayed sowing. Moreover, for early maturing, erect type varieties (RMO-40, RMO-225 etc.) the seed rate for sole crop may be used @ 12-15 kg ha^{-1} because these varieties have to be closely planted. Seed rate for spreading and semi spreading types (Jawala, Jadia, IPCMO-880 or CAZRI Moth-1) may be kept around 10 kg ha^{-1}.

Planting of moth bean in Western Rajasthan is advised to be practiced just next day of the rainfall (30-40 cm), otherwise germination may be reduced due to fast depletion in soil moisture and blowing of fast winds leading to the covering of seeds by dry sands. Moth bean, may not be planted as boardcast but line sowing with planter may be preferred. For erect type varieties (RMO-40, RMO-257, RMO-225, RMO-435) close planting 30-35 cm whereas, for Jawala, Jadia and CAZRI Moth-1 planting at 50-60 cm may be quite useful. After sowing of crop, proper planking is necessary to avoid soil moisture losses and seed losses by birds and mites from the open furrows. In the wake of delayed monsoonic rains, close planting with increased seed rate irrespective of the varieties may be practiced.

Sowing Time:

Planting time is very crucial for optimum production realization in arid situations. However, moth bean being rainfed dependent crop, its sowing times like other arid crops, basically depends on the onset of monsoon and the effective shower at a time (30-40 cm).

Investigations carried out at different centers on this aspect indicate that early (Ist week of July) planting may lead to vigorous and luxuriant growth and plants become taller (upto 50-60 cm) resulting in poor bearings. However, bit delayed sowing may lead to shorter plant height, restricted canopy and profused bearing. Hence, in Western part of Rajasthan, optimum sowing time by and large is 15-25th July. The delayed sowings may invite YMV problem. For Maharashtra situations, last week of June has been found optimum sowing time, whereas, for Haryana and Gujarat situations optimum sowing time has been found first week of July.

Microbial Fertilizer/ Seed Treatment: It is customary to grow legumes in a crop rotation and sequence because of their capacity to fix atmospheric nitrogen, enriching the soil and making the nitrogen available to the companion and leguminous crop. However, inoculation with the right type of rhizobial culture and favourable soil conditions (near neutral pH, soil aeration, adequate soil nutrients like, Ca and Mo) are of great importance for effective nodulation which are maximum upto flowering and cease at pod formation, onwards.

Studies conducted at Mandore station indicated that rhizobium strains MRB-5 and MT-20 improved the nodulation and increased the grain yield of moth bean by about 16.1 and 13.8%, respectively, over the control as stated in Table 5.

Table 5: Effect of rhizobium strains on nodulatin and grain yield of moth bean.

Rhizobium strains	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Nodules plant^{-1} (No.)	Dry wt. of nodules plant^{-1} (mg)
MRB-5	520	2782.0	29.5	106.0
MT-20	510	2710.0	27.2	96.0
Control	448	2262.0	21.5	73.5

Source: Anonymous, 1993

Thus, seed treatment of moth bean with appropriate Rhizobium culture may give additional yield advantage. For treating 8-10 kg seeds sufficent for one hectare, 250 g of *gur* is dissolved in one litre of hot water. On cooling, sufficient water and 625 g of *Rhizobium* culture are added and mixed thoroughly. The *gur* / culture slurry is slowly poured on the seed lot. On doing so, the seeds are briskly stirred to ensure that all the seeds are thoroughly contacted. Study also indicated that use of 400 g of row gum in the slurry may also be quite effective for sticking of seeds with the culture. Prior to the *Rhizobium* treatment, the seeds are also treated with fungicides like, Captan, Thiram or Agroson GN @ 1-3 g kg^{-1} seeds.

Fertilizer Management:

Moth bean is generally grown on the neglected and less managed soils, which are inherently poor in physical properties and deficient in organic matter. Hence, in view to improve organic carbon and physical properties of the soil, application of fully decomposed Farm Yard Manure (FYM) to the tune of 20-25 t ha^{-1} should be applied. Besides, meeting the above requirement of the soil, the same would also help increase water holding capacity of the soils. Being legume, it meets its N requirement through biological nitrogen fixation, however, studies do indicate that 10 kg N ha^{-1} may be applied at the same planting time. Pulses in general, including moth bean respond to phosphorus because the same may help extract insoluble phosphorus from the soils. Yield levels of moth bean have been observed to be increased by the applications of P_2O_5 upto 40 kg ha^{-1} at the sowing. An application of 40 kg P_2O_5 ha^{-1} in the form of DAP increased grain yield by about 20% over 20 kg P_2O_5 in Mandore situations. The applications of 10 kg N+40 kg P_2O_5 ha^{-1} has proved the effective starter dose, hence, may be applied with.

Weed management:

Weed infestation particularly, in rainfed crop greatly compete with the soil moisture, nutrient and spread of the canopy, hence, their irradication before the critical growth stage may be considered important crop production input in moth bean. It is desired that moth bean crop may be kept completely free of weeds at 20-25 days of sowing. Weed infestations after

this crucial stage may not cause any tangible yield losses because canopy will help suppress weeds. Effective ploughing before sowing may also prove very important for keeping the weeds under control. The studies carried out at Bikaner, Fatehpur and S.K.Nagar centers have conclusively indicated that both hand weeding at 30 days after sowing and incorporation of fluchloraline@1.0 kg/ha^{-1} pre plant incorporation may prove equally effective in controlling weeds and increasing grain yield of moth bean (Table 6).

Table 6: Effect of weedicides on grain yield of moth bean.

Treatment	Grain yield kg ha^{-1} of moth bean				
	1997	**1998**	**1999**	**2000**	**Mean**
Weedy crop	695	581	205	161	410
One hand weeding at 30 DAS	1093	878	371	337	670
Fluchloraline@ 1.0 kg ai pre plant incorporation	910	853	427	328	629

Harvesting and Storing:

Moth bean like other pulses suffers from harvest (shattering), transport and storage losses. According to an estimate, 8-20% or even more yield losses are expected due to these factors. Hence, harvesting and storage have to be very effectively done. The crop may be up-rooted when leaves dry up and the pods turn light yellow. All plants are stored in the form of heap and sun dried for 3-5 days. Thereafter, threshing is done by bullocks, threshers or by the use of hand sticks. After threshing, the seeds are again dried in the open sky until their moisture content lowered down to approximately 8-10%. Seeds are stored in air tight earthen pots by using gunny bags or cloth bags. Grains to be used for seed purpose may be treated with Endosulfan powder, whereas seeds are not at all treated, if preserved for edible purposes.

DISEASES AND THEIR MANAGEMENT

Moth bean, a known drought hardy pulse, is important source of grain and fodder. Crop is endowed with ability to fix atmospheric nitrogen through symbiosis with the *Rhizobium* strains, which are adapted to the neglected lands and harsh environment. Inspite, of inherent practical potential, emboded in this crop, production in problematic arid regions is considerably affected due to obvious agroclimatic reasons, poor soil fertility status and the ravages of diseases and insect pest problems. Moth bean has been so neglected as far disease management is concerned that, it has inspired few articles on practical diseases management during past half decade. However, there are a number of pathogens which affect moth bean crop causing substantial yield and quality losses to grain and fodder produce. Inspite of severe disease problems, the attempts on disease management through chemicals have not been undertaken at the farmers'level but practically management strategies being employed, are the use of tolerant genotypes to some extent only. However, sincere efforts during past 20 years or more have been undertaken on finding out the causes, symptoms and the management of diseases in moth bean. The disease expression in moth bean can be classified due to abiotic, mesobiotic or biotic causes.

1. Non-pathogenic causes:

i) Mechanical injury: During hot and dry weather, high wind velocity may lead to sand movement, and hot sand particles may, therefore, rupture the leaf epidermis, leading to minute wholes or whitish web like structure, the plants may ultimately die out giving dry yellowish symptoms. The injury may be most common at the maturity when low soil moisture may accompany high scorching winds.

ii) Hot steaming: High wind velocity towards September ends when soil moisture is almost depleted, may cause disorder in growing leaves, leading to mortality of plants with yellowing and drying symptoms.

The control measures against these physical injuries are difficult, however, early planting of crop or planting of early maturing varieties may escape such scathing injuries to some extent.

2. Mesobiotic causes:

i) Yellow Mosaic Virus: Yellow mosaic is regarded as the most serious and devastating viral disease of moth bean, it starts appearing on the young leaves and considerably affects growth, pod set and yield of moth bean plants (Plate 4). Yellow mosaic causing virus is transmitted through white flies (*Bemisia tabaci* Genn.).

ii) Losses: It may occur at any stage of plant growth, however, if occurs at the initial stage may result in slow growth, delayed flowering, poor pods, great loss to the canopy chlorophyll, causing yield reduction even upto 90%. Reports also indicate that yield losses depending on the intensity and severity of disease may reach upto 100%.

Symptoms:

1. Initial visible signs are the appearance of yellow spots scattered over the leaf, expanding rapidly.
2. Leaves depict yellow patches alternatively with green areas, the latter may turn yellow.
3. Completely yellowish leaves may give whitish look and ultimately may become necrotic.
4. Plants may show decreased growth.
5. Plants bear few, small and curled pods which bear few and shriveled seeds.
6. Plants show distinct stunted growth, golden yellow look of the leaves and their curling behaviour.

Control:

1. Local varieties are highly susceptible to YMV infection, these may be replaced by YMV resistant varieties, CAZRI Moth-1, Jawala and early maturing ones, like RMO-40, RMO-257, RMO-225. These varieties have shown field resistance against YMV (Plate 4).
2. Population build-up of vector (white flies) may help disease spread rapidly. Studies from Fatehpur revealed that vector of YMV could be controlled by single spray of

YMV resistant variety: Jawala

Incidence of YMV in Moth bean

Plate - 4

monocrotophos (0.04%) at 35 DAS. Rogor (0.02%) sprayed twice at the interval of 15 days has also proved most effective.

3. Guar is the most effective trarp crop for checking white flies and, therefore, spread of YMV.

II) Bacterial Leaf Spot: This disease is most common in Rajasthan. It spreads rapidly during high humidity. A distinct race of *Xanthomomas phaseoli* was identified as the causal bacterium of this disease.

Symptoms:

1. Many small, large and irregular brown necrotic spots appear on the leaves proving very severe on the leaves.
2. These patches are more prominent on upper than on lower leaf surface.
3. Minute water-soaked round irregular spots appear in group on leaf surface, their sizes increase and turn brown to black.
4. In the extreme cases, leaf may fall down.
5. Ultimately petioles, stems and pods may show extended brown spots.

Control:

1. The genotypes viz., IC-8833, Amravati local and PLM-11 were found resistant under artificial inoculation against Bacterial leaf spot.

2. Other cultivars viz., RDM-63, RDM-168 and RDM-182 also showed resistance to Bacterial leaf spot under artificial inoculation.

3. Seed treatment with Streptocyline (0.01%) + Captan (2 g kg^{-1} seed) was found better in reducing primary infection of Bacterial leaf spot/blight.

4. The intensity of Bacterial leaf spot/blight could be reduced by three sprays of Blitox (0.3%) / Streptocycline (0.01%) + Blitox (0.3%) / Bavistin (0.05%) + Blitox (0.3%) as given below (Table 7) :

Table 7 : Management of Bacterial leaf spot/Blight of moth bean (cv: Jadia) through spray schedules (Mean over 3 seasons 1987-89).

Treatment	Average infection index	% Disease control	Seed yield (kg/ha)	% Increased yield over control	Fodder yield (q/ha^{-1})
Blitox 50 WP (0.3%)	19.35	64.43	4.29	14.09	19.56
Streptocycline (0.01%) + Blitox 50 WP(0.3%)	30.50	48.66	4.58	21.80	19.23
Bavistin 50 WP (0.05%) + Blitox 50 WP(0.3%))	21.65	63.56	4.32	14.89	2.54
Control	59.41	-	3.76	-	18.16

Source: Technical moth bean Report No. 2; 1992. Agricultural Research Station, Fatehpur.

Fungal diseases:

Macrophomina phaseolina (Tassi) is most destructive, potential and stable fungal pathogen of this crop causing root rot, seed rot, seedling blight, collar rot etc., in all the moth bean growing areas. Population of this pathogen increases when moth bean is succeedingly grown in the same field. It appears in hot and dry climate. Fungus remains widely distributed in the soil. Maximum damage is caused at the seedling and plant maturity stage.

Symptoms:

1. Infected seeds appear deformed, dull and smaller in size, most of them may not germinate.

2. Collar regions of the emerging seedlings turn reddish- brown showing discoloration.
3. Discolorated area turns dark brown and infected seedlings may die in hot and dry weather.
4. The discoloration of stem starts with reddish-browning at collar region, subsequently whole plant may wilt out.

Control:

1. Seed treatment with carbendazin (2 g kg^{-1} seed) has been observed most effective in control of this disease.
2. Seed treatment with Bavistin @2g kg^{-1}, Captan @3 g kg^{-1} and Topsin M70 @2 g kg^{-1} seeds may effectively reduce disease intensity and post emergence mortality of the plant.
3. The fields may be irrigated when soils dry up and temperature rises.
4. The biocontrol agent like *T. Harzianum* causes maximum growth inhibition of *M.phaseolina* isolated from moth bean.

Brown Web Blight: This disease appears during heavy rains and high temperature. Disease occurs through soil, seeds and naturally infected hosts. Temperature of 25-30^{0}C and RH of 85% is most congenial for the development of this disease. Losses due to this disease are more severe at the seedling stage.

Symptoms:

1. Light small round web like patches can be seen on both surfaces of the leaves.
2. Every plant part but flower can bear the patches.

Control:

1. Inclusion of non-leguminous crop in the rotation.
2. Close planting may be avoided.
3. Seed treatment with Benlate and Brassicol @ 2g kg^{-1} seed may result in complete elimination of seed-born infection.

INSECT-PESTS AND THEIR MANAGEMENT

Moth bean is profusely grown in dry habitats of Rajasthan. Many inherent characters like deep roots system, drought and heat avoidance potential, high photosynthetic ability, wider canopies contribute towards its adaptation to the situations where other crops may hardly survive. Even though, crop acquires rich and efficient morpho-phosiological attributes almost immune to water scarce and heat prone situations, the crop, however, doesn't exhibit immunity towards insect-pests damage. The crop harbours a number of insects having the status of pests, which considerably damage the crop causing, therefore, serious concern as far the crop productivity is concerned. The hot and dry weather may even prove catalistic for development of certain insects in this crop. More than 20 insect-pests affect this crop from sowing to harvesting and even during storage. Studies conducted at different places indicate that thrips, jassids, white flies, black weevils, pulse beetles and white grubs have occupied the status of major pests, whereas, other pests, like termites, mites and surface grass hoppers may be treated as the minor pests of moth bean at the varied places.

Extent of damage : Research efforts on insect pest damage, survey of different pests for varietal resistance and management strategies are limited to a few unsystematic studies. Research papers, review papers and the practical efforts are limited particularly, in reference to moth bean crop.

Some estimates by individual workers have been made on the extent of damages by particular pests in specific zones/situations. For instance, pod borers damage in moth bean in S.K.Nagar situations has been observed to 8.8%. The yield losses in susceptible genotypes of moth bean towards jassids and while flies have been reported even upto 70% in Jodhpur conditions. A total loss in grain yield of this crop due to insect-pest complex was observed upto 56% in Jobner situations. The damage may be more due to soil pests than foliage pests. The damage considerably varies with the soil type and the environmental conditions where this crop is grown. The important pests of moth bean have been discussed below:

i) **Jassids** : This pest remains active from vegetative stage to the crop harvest. The adults as well as the nymphs, suck the cell sap. The adult is a small insect and feeds on the leaves. There are many generations of Jassids during the year.

Symptoms : In case of heavy infestation, the leaves turn brown, curl and finally dry out, and shed on the ground.

Control :

1. Early sowing upto 10th July has resulted in good control of Jassids/thirps.
2. Intercropping of pearl millet + moth bean (1:4) has been found effective in lowering the population of Jassids compared to the sole crop.
3. Jassids can be effectively controlled by spraying monocrotophos / dimethoate (0.03%) or lindane (0.01%).
4. Varietal differences against tolerance to Jassids are insignificant.

ii) Whitefly : Whitefly is a serious pest of moth bean and acts as a vector for Yellow mosaic virus. Incidence of whitefly is generally at peak during second week of September. The nymphs and the adults suck the cell sap particularly, from the surface of the leaves.

Control :

1. Early sown crop upto 10th July shows low population of whitefly.
2. Pearl millet + moth bean intercropping (1:4) may reduce the population of whitefly effectively around 30 days after sowing.
3. Spray of Monocrotophos @ 0.25 a.i. ha^{-1} or dimethoate @ 0.15 kg a.i. ha^{-1} have proved quite effective against this pest.

iii) Thrips: Thrips also appear major insect pests in Gujarat and Rajasthan. The same are active during bud and flowering stages. Nymphs and adults suck the saps from the buds and the flowers leading to their drop.

Symptoms: In severe forms, buds and flower may drop on the ground.

Control:

1. Early sowing upto 30 June may result in minimum infestation of thrips, the same may, however increase with delayed sowing.
2. Dusting of Methyl-parathion (2.0%) or Melathion dust (5.0%) @ 25 kg ha^{-1} may effectively control infestation of thrips.

White Grub:

White grub is a serious scarab, damaging most of the rainfed crops including moth bean. The beetles which emerge out from the soils following rains are fed on a variety of host foliage trees. The beetles mate before returning to the soils for laying of eggs. Grubs have only one generation in one year. The grub feed on the roots from July to October.

Symptoms: Plants show varying degree of yellowing, get wilted and their sudden death is expected.

Management:

1. Collection of beetle by putting light trappers on the trees is the most convenient approach.
2. Hand collection of beetles is another simple physical approach.
3. Ploughing of fields for exposure of the grubs and picking up of these beetles.

Storage pests:

Damage to the moth bean seeds like other pulses is very serious during storage also. The most damaging bruchid is *Callasobruchus chinensis*. The peak damage is during April to September. The beetles are carried to the store from the fields alongwith the grains.

Control:

1. The threshold seeds should be dried to lower down the moisture content to about 10.0%.
2. The seeds in the store be treated with neem leaves and edible oil (preferably mustard oil).

USES AND QUALITY

Cultivation of moth bean is specially restricted in areas of dry habitats particularly in Northern-Western plains of Rajasthan. The crop has its domesticated uses in accordance with the need of rural masses. Thus, uses and adaptation have led this crop to sustain ecologically and socially. Multi-uses which are of routine in nature have been meeting the need of poor masses, making this crop household to every family. The abundant availability of moth bean grain produce appear to have engineered its uses at the brink of survival towards climatological uncomfortable tides. The uses may have been linked to the nutritive and tasty gradients available in moth bean seeds, its green foliage and the harvested dry stuffs, as well. Thus, statistics on the area of a crop commodity also largely depends on the preference and likings by the people, uses for the livestocks and its contribution to soil health and towards high degree of sustainability to unprecident environmental adversities. It has been, therefore, tried to link uses and qualities together in context of harsh environment.

Uses:

Moth bean is a multi-purpose crop and is considered as the legume of great economic uses in semi-arid and arid areas. Being pulse, its principal and the most common use is, a rich and cheap source of vegetable protein. The specific, local and other general uses are given below:

1. **Papad**: Papad prepared from the dough of moth bean flour, is an extra thin loven bread like structure. *Papad* is also prepared from the flour of moong bean and urad bean pulses. The *Papad* can be stored for months together for instant uses following baking or frying as snacks. The use of *Papad* as a part of snack is most primitive and general practice in India.
2. **Bhujia**: This is thick paste of fine grinded flour of decorticated moth (*mogar*) seeds mixed with appropriate quantity of spices to make semolina like thread medium which is finely fried. Its uses are most common across the zones.
3. **Dal**: This preparation is most usual like other pulses. The seed splits are boiled at

modest temperature, thereafter, spices are suitably mixed and cooked in water and served as hot semi-liquid dish. *Dal* is usually served alongwith unloven bread and with rice, as well.

4. **Mangori**: Wet decorticated seeds of moth bean grinded as thick paste with desired quantities of ginger, spices, *Coriander*, onion etc., are added to the paste. The paste is thereafter, cut in 2-4 g pieces and are sun dried. The resultant product known as *nuggets* are stored for years together for future needs as a substitute of vegetable, when the latter are not available during summer season.
5. **Vada**: It is prepared by mixing of *dal* flour with water spices, ginger and other essentials, the resultant paste is effectively fried with edible oil. The use of *Vada* is very common in India, as it helps improve gastric troubles, disorders and constipation. It also protects against sunstrokes, which are frequent in hot-arid regions.
6. **Kheech**: It is prepared by boiling moth *dal* and pearl millet seeds together in water to give thick paste preparation. A tasty dish is served with butter. *Kheech* works as an antiacid and as a cooling agent for rural people of arid areas.
7. **Roti**: It is prepared by mixing the flour of pearl millet and moth bean which is flattened and roasted on a hot plate.
8. **Sproutings**: Moth bean seeds are soaked in water for overnight and the sprouted seeds are consumed directly or they are consumed following their roasting with spices. Sprouting of seeds, break down anti-nutritional or flatulence factors due to their metabolization during germination. This process is also known to increase the ascorbic acid contents. Consumption of sprouted seeds is age old practice used by the poor villagers. The sprouted seeds may, sometimes be consumed as fried/roasted.
9. **Rabri:** A thick paste made up by mixing the flour of pearl millet and moth bean in butter milk, is kept over night. This increases the digestive capabilities. It also soothens stomach acidity and helps in realease of gas from the system. Further, it also works as a good sedative agent in hot and arid climates of Indian desert. During summers it also acts as a cooling agent.

10. Besides edible uses, moth bean is known as soil binder. Its dense mat like spreading behaviour of the canopy, completely covers the ground, therefore, reducing soil movement, it also shields soil from heat, preventing cracking and crust formation. It, therefore, reduces the soil organic matter and moisture losses.

Quality:

Moth bean offers a variety of edible products-vegetable, fodder for animals, whole seed, *papad, nuggets, bhujia* etc., hence, quality consideration of its grains and products is desired.

Studies have indicated that moth bean is a good source of amino acids, particularly of lysine, leucine and certain vitamins, like carotene. Among the protein fractions, albumins are important, which are found maximum with the fraction of 6.7 to 7.4% of total proteins.

Composition of moth bean seed and herbage have revealed that it is a good source of protein and carbohydrates, alongwith substantial amounts of fibre, minerals but sulphur containing amino acids (Cysteine and Methionine) are found in lesser quantity. Generally late sown crop may show low protein contents in grains than early/normal sown crop.

Varietal differences: Recent (2000-2001) chemical analysis revealed that considerable varietal differences existed among the strains evaluated through AICRP on Arid Legumes:

Thus, strain CZM-45 is characterized with maximum grain protein(26.13%), where as, IVPD was maximum in CZM-12 (55.4%). RMB-50 proved improved as far tannin content is concerned. RMB-24 took only 13.0 minutes for cooking (Table 8).

Among the recently released and old popular varieties, it is RMO-435, which had maximum grain protein (27.50%) whereas, other early maturing variety generally contained low protein. However, variety CAZRI Moth-1 and RMO-435 may be characterized with maximum digestible protein (Table 9). CAZRI Moth-1 also took less time for cooking, whereas, RMO-435 and Jawala took more time for cooking. Tannin an undesirable component was minimum in RMO-225 and RMO-40 (334 mg g^{-1}). Thus, recently released varieties of moth bean along with possessing high grain yield potential, having field tolerance to YMV appreciably looked improved in quality parameters also in one way or other.

Table 8: Chemical values of certain improved genotypes of moth bean

Parameter	Minimum		Maximum	
	Variety	Value	Variety	Value
Crude protein (%)	CZM-18	23.0	CZM-45	26.13
IVPD (%)	RMB-50	44.1	CZM-12*	55.4
Tannin (mg g^{-1})	RMB-50	0.32	RMO-225	0.77
Carbohydrates(%)	CZM-12*	49.1	CZM-18	57.5
Moisture content (%)	RMO-225	6.2	RMB-24	7.0
			RMO-11	
Cooking time (min)	RMB-24	13.0	RMM-101	17.0

Source : Annual Report, AICRP on Arid legumes, 2002

Table 9: Important quality parameters of certain commercial varieties of moth bean

Parameters	RMO -225	CAZRI Moth-1	RMO-435	RMO-40	RMO-257	Jawala
Crude protein(%)	24.53	25.00	27.50	24.50	18.77	19.88
IVPD(%)	47.5	54.0	53.2	47.2	48.2	48.4
Cooking time (min)	15.5	15.0	22.5	20.0	26.0	22.0
Tannin content (mg g^{-1})	334	390	378	334	380	383

Antinutritional factors and their removal:

Like other pulses, certain antinutritional factors like, trypsin inhibitors, saponins, phytic acids etc., are also found in moth bean. Studies carried out have indicated that by sprouting/ cooking the seeds, these factors could be removed considerably. For instance, the trypsin inhibitors activity was reduced upto 98% by cooking of sprouted seeds or pressure cooking of seeds. Similarly, saponin activity could be reduced by about 77% on cooking of sprouted seeds. Protein digestibility is generally known to be increased by about 20-50% on cooking of seeds.