Progress and status of yam bean research in India

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Abstract

Yam bean (*Pachyrrhizus erosus*) is a native of Mexico and Central America and is widely cultivated throughout the tropics, in both hemispheres. In India, it is popularly grown in parts of West Bengal, Bihar, Orissa and Assam approximately in an area of 200 to 300 ha. The plant has many uses: the young tubers are edible and rich in ascorbic acid, while mature tubers yield high quality starch and the seeds can be used as insecticides. Central Tuber Crops Research Institute (CTCRI) and All India Coordinated Research Project on Tuber Crops centres especially Rajendra Agricultural University, Dholi maintains more than sixty germplasm accessions collected from different parts of India. One yam bean variety "RM 1" was released by AICRPTC centre at Rajendra Agricultural University. Parental material for initiating breeding work has been isolated at CTCRI. Yam bean genotype L-19 was found to be highly suitable for Orissa. Agronomic practices for cultivating yam bean have been standardized. Work on intercropping of yam bean is also in progress. Stem borer is the major pest on yam bean and sometimes diseases like severe blight spots on leaves, stems and pods could also be seen. Yam bean seed extract was found to be a biocide for *Sitophilus oryzae* and *Aphis craccivora.* Aphids on taro and cowpea can be controlled by yam bean seed extract. Yam bean starch characterization is done. Seeds are multiplied at CTCRI Regional Centre in Bhubaneswar and at AICRPTC centre at RAU, Dholi for distributing to farmers.

Introduction

Yam bean (*Pachyrizhus erosus* (L) Urban), also known as potato bean in English, belonging to the family Leguminaceae and sub family Fabaceae (Papilionaceae), is a starchy root crop with comparatively high sugar content and a moderately good source of ascorbic acid. In India, tender tubers are consumed as a fruit and the taste resembles that of Chinese water chestnut. Its crisp and fruity underground tubers are eaten raw. It is commonly called Misrikand, Kesaru, Shankalu or Sankesh in different parts of India. Tubers contain more than 82% water, 1.5% protein, 10% starch and 5-6% sugar. The mature seeds have high content of alkaloids and insecticidal properties. In India, it is mostly grown in North Bihar extending parts of West Bengal, Assam, Orissa and eastern Uttar Pradesh. As it is a crop of small farmers, information on area and production of this crop has not been documented. Large area under yam bean is in Bihar state of India from where it is marketed all over the country. It is also a popular crop in the gangetic alluvial tract of West Bengal.

The advantageous features of yam bean are: good adaptability to a wide range of climatic and edaphic ranges, well balanced and nutritious composition of protein/ starch contents, acceptable taste, good post harvest/ storage characters, biological N fixation etc. Owing to these features the crop should be effectively exploited to meet a wide range of needs in developing countries. Research work carried out in India on breeding, agronomy and utilization of yam bean seed extract for crop protection aspects are briefly summarized.

Germplasm accessions

The germplasm accessions are being maintained at CTCRI (63 nos.) and AICRP Centres (205 nos). The germplasm accessions comprise of land races and exotic collections. Most of the exotic collections are from Mexico. All the accessions from CTCRI were characterized and evaluated. Except one with white flowers, the remaining accessions produce velvet flowers. The tuber yield of the accessions ranged between 10.33-25.78 t ha^{-1}. Five accessions were identified with yield more than 25 t ha^{-1}. Analysis of the biochemical constituents of the tuber revealed, variations in dry matter (9.33-29.78%), starch (3.02-7.96%) and sugar (3.02-7.96%) contents (Vimala, Personal communication).

Breeding efforts in yam bean

Yam bean research in India has not received much attention from the national research system. Hence farmers in the country still rely on traditional land races. In India, research on yam bean is being undertaken at Central Tuber Crops Research Institute (CTCRI), Thiruvananthapuram, Kerala, India and two centers (Bihar and West Bengal) of the All India Co-ordinated Research Project on Tuber Crops (AICRPTC). There has been little attempt for genetic improvement through breeding. Breeding in yam bean is limited to selection only. Nature of compatibility was studied in a set of diallel crosses involving eight genotypes. The breeding objectives include earliness, high dry matter, improved nutrition, drought tolerance and pest and disease resistance. Attempts have already been made to develop hybrids of Mexican and local types and some of the lines were promising (Mnukhopadhyay *et al.*, 2008).

Induction of variability through mutagenesis

The information available on the breeding of this crop is very much limited in India. Genetic variability is limited in yam bean. For inducing specific genetic changes, an exploratory gamma irradiation was carried out in seed samples of a superior collection (Sreekumari *et al.* 1983; Nair and Abraham, 1988, 1989). Yam bean seeds treated with gamma radiation (5 - 25 kR) or ethylmethane sulphonate (EMS, 0.5 – 1.25%) induced greater variability with regard to shoot length, number of branches, number of leaves and tuber yield. Treatment with gamma radiation greater than 7.5 kR significantly reduced vegetative vigour and yield. Yam bean seeds treated with gamma radiation (5 kR) stimulated vegetative vigour, induced greater shoot length, number of branches, number of leaves and tuber yield than control plants. The occurrence of multiple shoot (twins, triples and quadruplets seedlings) which accounted for nearly 2% of germinated seeds has also been reported in yam bean (Sreekumari and Abraham, 1980).

Varieties

Though, a native of Mexico, the crop is well distributed in the tropics. Yam bean is one of the under-utilised tuber crops which has been gaining importance in recent years. In India two types of cultivars (Mexican and local) are grown. Mexican types are larger in size and attain a diameter of 10-15 cm and weigh up to 1.5 – 2.0 kg. The Mexican types are less sweet compared to local ones and develop cracks on tubers. The local types have smaller tubers (200 – 300 g), moderate to high sweetness, less fibre, conical shape, white flesh and are soft with creamy skin. They do not develop cracks on tubers. Rajendra Mishrikand 1 (RM-1), an improved selection, released by the AICRP on tuber crops is very popular in Bihar and West Bengal. Its average tuber yield is 40 – 55 t ha^{-1} in 110 – 140 days. The individual tuber weighs 0.6 – 0.7 kg, sweet, comparatively free from cracking with smooth surface, napiform with cream coloured tuber skin. Flesh is white. Other promising Mexican line L-19 produces better yield in Bihar, West Bengal and Orissa.

Agro-climatic requirements

Yam bean requires a hot humid climate and adapts well in sub-tropical and hot temperate zones. The basic requirement is frost free condition during the growth period. It grows up to an altitude of 1000 m. It has been observed that thermo-periodism has got a definite effect on tuberization. Though yam bean requires 14-15 hours of photoperiod for good vegetative growth, shorter days are preferred for better tuberization. Hot days and cooler nights favour tuberization. A well distributed rainfall during the growth period is required for optimum tuber yield. Excessive rain is deleterious to the crop. Cool climate during early growth period adversely affects the tuber initiation and also results in a prolonged vegetative phase.

Fertile, well drained, sandy loam soil is best suited for cultivation of yam bean. This crop adapts well to loamy and clay loam soil. It can tolerate a higher clay content if the soil is well drained with good humus content. Water logging adversely affects yam bean cultivation. Optimum soil pH requirement is 6.0 - 7.0.

Agronomic research in yam bean

Research work done so far on the Agronomy of yam bean has enabled the development of the following production technologies for yam bean cultivation in India:

Planting season, spacing, method and seed rate

Traditionally yam bean is sown during June-July with the onset of rain in North-Eastern India and is usually harvested in December-January (Varma *et al.*, 1996; Palaniswami and Shirly Raichal Anil, 2006). The time of sowing of seed varies from June to September according to the purpose of the crop. For seed purpose, seeds are sown during June-July at a spacing of 30 x 30 cm (Ravindran, 2000). If smaller size tubers are required, seeds may be sown in August-September at a closer spacing of 30 x 15 cm or even 15 x 15 cm. When the crop is sown late in September and harvested in December-January, it gives a comparatively lower yield due to smaller sized tubers. Tubers from this late crop are free from cracking and can fit well in various multiple cropping systems as it is a short duration crop. The ideal time of sowing yam bean was from September to middle of October, beyond which growth, tuber development and quality are reduced drastically due to lower temperature under gangetic alluvial zone (Sen *et al.* (1996). In Uttar Pradesh, the crop is sown during September to October. In Maharashtra, the plant population, when grown on ridges, was optimized at 1,33,000 per ha (Bhag Mal and Kawalkar, 1982). In field experiments conducted at CTCRI, Regional Centre, Bhubaneswar to study the effect of spacing on dry matter production and tuber yield, significantly highest dry matter production per plant (64.3 g) and tuber yield per plant (144.3 g) were recorded at 60 x 60 cm plant spacing. The spacing of 60 x 30 cm also produced reasonably good size tuber (109.8 g per plant) with moderate yield (4.62 t ha^{-1}) (Nedunzhiyan *et al.,* 2001).

Deep ploughing of land twice using a mould-board plough is essential. Plank the soil after each ploughing to have a well pulverised soil as well as to conserve moisture. A good tilth is required for yam bean cultivation. Yam bean seeds can be sown on hills at the rate of 3-5 seeds per hill. Hills are prepared at a spacing of 0.75 - 1.00 m with 15 cm height. Planting the seeds on ridges resulted in better yield (Ravindran, 2000).

Yam bean is usually raised by seed. The seed rate varies according to the spacing adopted. Normal seed rate is 20 - 60 kg $ha^{\cdot 1}$ depending upon the time of sowing of seed, spacing and the purpose (Ravindran, 2000). In Uttar Pradesh, the seed rate recommended is 62-74 kg ha^{-1} (Srivastava *et al.*, 1973).

Nutrient management

Despite the earlier evidences that there is no need to supply additional N to this leguminous crop, many workers have found later that yam bean responded positively well to application of N fertilizer. Yam bean responds well to nitrogen application and 120 kg N ha^{-1} is optimum for both tuber and seed production (Nath *et al* 2007). Nutrient requirement is standardized for yam bean as FYM @ 15-20 MT or compost along with NPK @ 80:40:80 kg ha^{-1} under the aegis of AICRPTC centre at Rajendra Agricultural University, Dholi (North Bihar). Entire dose of P and K is applied as basal dose at the time of planting along with half dose of N and the remaining half dose of N is top dressed at 40-50 days after sowing along with interculturing and earthing up. A fertilizer dose of 80:60:80 kg N, P and K ha^{-1} is recommended for the state of Tamil Nadu (Ramaswamy *et al.,* 1980). In West Bengal, the maximum tuber yield was obtained with NPK @ 120:60:80 kg ha^{-1} (Sen and Mukhopadhyay, 1989). There is no significant influence of fertilizer application upon total soluble solid content of tubers. Higher levels of K (150 kg ha^{-1}) and split application reduced cracking of tubers and enhanced marketable grade tubers (Mishra *et al.,* 1993*).* However, either levels or methods of application of K could not affect the chemical constituents of yam bean tuber.

Reproductive pruning

Flowering in yam bean commenced from 58-68 days after sowing and lasted up to 92-103 days (Prasad and Prakash, 1973). Normally, yam bean starts flowering 75 days after sowing (Ravindran, 2000). For getting better tuber yield it is desirable to remove the flowers without allowing the plant to bear pods. There is significant negative correlation between tuber yield and pod formation. It is essential to remove the buds before they flower. Removal of buds by hand is the usual practice. Deflowering by spraying 2,4-D (50 ppm) at the flower initiation stage causes dehiscence of flowers and results in better yield of tubers (Mishra and Mishra, 1985; Ravindran, 2000). Manual deflowering is the most efficient up to 10 days after removal, but the efficiency steeply declined thereafter due to emergence of new flushes of flower buds (Panda and Sen, 1995). Highest mortality of flowers and thereby highest tuber yield was obtained by spraying NAA (1500 ppm) at flower bud initiation stage.

After care

Weed infestation is more in a June - August sown crop compared to September sown crop. The field is kept weed free by mulching the crop. Mulching also regulates soil temperature and conserves soil moisture. The first

interculturing is done at 40 days after sowing and the remaining half dose of nitrogen is applied along with earthing up. Second weeding is done 30 days after the first weeding.

Irrigation

Normally, yam bean is grown as a rain-fed crop but one or two irrigations particularly in the drier months promote tuber development. Frequent irrigation with higher doses of fertilizer makes tubers more succulent and reduces keeping quality. Normally there is no need to irrigate a June-July crop. In case there is scarcity of rains, irrigation is necessary as yam bean requires adequate moisture. For September sown crop, supplementary irrigation increases tuberization.

Mulching is also practiced for conserving soil moisture under rainfed cultivation of yam bean. Paddy straw mulching encouraged branches per plant, total dry matter production, crop growth rate, average tuber weight and tuber yield (26.3 t ha^{-1}), 26.4 % more than rain-fed situation (Jana, 2005).

Cropping systems involving yam bean

In West Bengal, intercropping yam bean with pigeon pea in 3:1 proportion proved to be remunerative and generate highest net return and B:C ratio of 4.62 (Panda *et al*., 2003). NK @ 80 kg ha^{-1} applied in two splits produced highest marketable tuber yield of yam bean and grain yield of pigeon pea (Panda *et al.* 2003). The residual effect was studied in the succeeding mung bean crop. For highest grain yield of succeeding mung bean, NK level of 100 kg ha^{-1} is required. In North Bihar, yam bean is intercropped with maize, where maize plants are utilized as trailing stand. But in other parts of India, normally trailing is not adopted for growing yam bean. Cowpea (fodder)-jute-yam bean, maize-rice- yam bean, sesame-rice-yam bean, green gram- upland taro- yam bean, green gram- elephant foot yam- yam bean and ground nut- rice-yam bean crop sequences are possible and yields of yam bean remained unaffected (Panda *et al.* 2003). Moreover the sequence cowpea (fodder)-jute-yam bean and ground nut- rice-yam bean improved the soil nutrient status. Kharif maize – yam bean – onion and kharif maize-yam bean- wheat + moong are feasible and economically viable cropping systems (Singh and Singh, 2008).

Harvesting

In India, yam bean is harvested at 150 days after sowing (DAS). But it can be harvested after 100 days according to the demand in the market and smaller sized tubers fetch better market price. However, optimum time of harvesting is 90 - 105 DAS in certain part of the country (Nedunzhiyan *et al*. 2001, 2002).

If harvesting is delayed, chances of cracking of tubers are more. This in turn results in the deterioration of tuber quality and thereby affecting market value. Shallow irrigation may be given just before digging the tubers manually. The above ground portions are trimmed before digging out the tubers. Harvested tubers can be stored for 2-3 days without any deterioration. If the tubers are stored for a longer period, the creamy colour of the skin changes to purplish brown and loses water, which causes reduction in weight. The harvest can also be delayed by leaving the crop in the soil without removing top portion. The seed crop is usually harvested 240 days after sowing *ie* during March-April. The seed pods are generally harvested when they start drying and beans obtained by beating the pods with sticks.

The average yield of local cultivars is 18-20 t ha^{-1} while that of improved varieties like Rajendra Mishrikand is 36-40 t ha^{-1}. With improved cultivation practices it is possible to get an yield of 40-45 t ha^{-1} and a net profit of Rs.12000-15000 ha^{-1} (One US $ = INR 50).

Pests and diseases management

No serious pests are reported in yam bean. Root rot and mosaic are the common diseases. Root rot (*Sclertotium rolfsii*) affects the crop under water logged conditions. Providing good drainage prevents the disease incidence. Use of disease free seeds and field sanitation reduces the mosaic incidence (Devadas, 2007). But when the crop is grown for seed purpose, pod borer becomes serious. Leaf blight in germ plasm accessions is reported (Jeeva, Personal communication).

Insecticidal properties of yam bean extract

Mature seeds of yam bean contain a toxic compound called rotenone ($C_{23}H_{22}O_6$) which has insecticidal properties. Detailed studies were conducted at CTCRI on the efficacy of yam bean seed extracts on various pests which are common on stored products of tropical tuber crops. Petroleum ether extract of yam bean seed (YBSE) 3% was effective against adults of *Sitophilus oryzae* and larvae and adults of *Tribolium castaneum.* Yam bean seed extract (@1%) resulted in high mortality (over 95%) at 5 DAT of field pests such as *Aphis craccivora* Koch (cowpea aphids), *Spilosoma obliqua* Walker (Bihar hairy caterpillar), *Spodoptera litura* Fabricius (army worm) and *Pericallia ricini* Fabricius (castor defoliator) (Jayaprakas, Personal communication).

Future thrust

Yam bean will be an important crop to meet the nutritional and fuel requirements in the near future. Hence more scientific knowledge has to be generated about the production and chemical constituents to exploit the potential of the crop. Yam bean is a leguminous tuber crop and its cultivation improves the soil fertility. The crop comes up well even under semi arid conditions and gives good tuber yield indicating that there is scope for extending its cultivation to non-traditional areas to improve the rural economy. All the wildest possible range of endangered land races of yam bean should be conserved both *in situ* and *ex situ*. Early maturing, high yielding varieties with improved nutritional qualities, resistance to biotic and abiotic stress is to be developed. Low cost crop management practices need to be standardized for high yield and quality of yam bean. There is need to study fatty acid composition of seed and processing technique for eliminating rotenone from seeds.

In India, the young tubers are consumed and other uses of the various plant parts especially that of pods are yet to be exploited as there is wide scope for it. Emphasis should be given to exploit yam bean pods on a commercial basis for production of rotenone based crop protective agents.

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