Advanced Agricultural Research & Technology Journal ▪ Vol. IV ▪ Issue 1 ▪ JANUARY 2020 ISSN: 2581-3749 (online)

Special Issue

Climate Resilient Production Technology for Tuber Crops in Konkan Region of Maharashtra

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Abstract

Tuber crops hold distinct position among various food crops in tropical and subtropical region and possess great potential to exploit as substitute staple food crop. Cassava, sweet potato, elephant foot yam, colocasia, xanthosoma, aerial yam, yam bean have cultivation prospects under coastal climatic conditions of Maharashtra as sole crop or in cropping system. The various climatic vulnerabilities like drought, water logging during flood, extreme temperature and solar radiation aggravate nutritional deficiencies and pest and disease incidence affecting quality and yield of these tuber crops. But these crops possess ability to tolerate drought and shade and are adaptable to marginal environment, low input situation, adverse soil and climate with better flexibility to thrive in mixed cropping system. A review of research carried out in Konkan region of Maharashtra on various tuber crops and recommended technologies pertaining to varieties, production protocols, appropriate nutrient management, proper harvesting and storage along with integrated plant protection measures for sustainable production of tuber crops under aberrant climatic conditions is presented here.

Keywords: Tuber crops, climatic fluctuation, varieties, agro techniques, plant protection, value addition.

Introduction

Tuber crops are energy bank of nature and are third important group of food crops after cereals and grain legumes feeding about one fifth of the world population. These crops possess a plentiful potential as secondary staple food and vegetables besides enormous scope in feed and agro-based industries. Cassava (*Manihot esculenta*), sweet potato (*Ipomoea batata*), elephant foot yam (*Amorphophallus paeoniifolius*), colocasia (*Colocasia esculenta* var. *esculenta* and var. *antiquorum*), Xanthosoma *(Xanthosoma sagittifolium)*, aerial yam (*Dioscorea bulbifera*), greater yam (*Dioscorea alata*), lesser yam (*Dioscorea esculenta*) yam bean (*Pachyrrhizus erosus*), and arrowroot (*Maranta arundinacea*) provide their vital tubers, leaves and stems for cooking delicious foods. These are also well known for their starchy storage below the ground and constitute a major component of indigenous food, especially for tribal population. Tubers are good source of beta carotene, antioxidants, dietary fibre and minerals (Padmaja *et al.* 2013). These crops' adaptation to marginal environments, contribution to household food security and great flexibility in mixed farming systems make them a unique component of a targeted strategy that seeks to improve the welfare of the rural poor and to link smallholder farmers with those emerging growth markets (Scott *et al.* 2000). Effect of climatic fluctuations on tuber crops, various climatic vulnerabilities such as drought (less drought or mid-season droughts), water logging during flood and cyclones, temperature extreme and solar radiation accelerate reduction in productivity and deteriorate quality due to nutritional deficits as well as pest and disease incidence (Mhaskar *et al.* 2017). Tuber crops have strong tolerance to climatic aberration under coastal climatic conditions. These crops sustain even under different climatic vagaries such as increased

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Received Date: 1.10.2019; Accepted Date: 8.12.2020

rainfall and prolonged dry spell. Tuber crops can tolerate drought and shade and are adaptable to marginal environment, low input situation, adverse soil and climate with great flexibility to thrive in mixed cropping system (Mhaskar *et al.* 2017).

The extensive research resulted in development of suitable varieties, planting protocols, integrated nutrient management, harvesting techniques, post-harvest handling and appropriate plant protection measures for sustaining production of quality tubers under climatic fluctuations.

Varietal Development

Several improved varieties of tuber crops *viz*., elephant foot yam, colocasia, xanthosoma, aerial yam, greater yam, lesser yam are available.

The sweet potato variety *Konkan Ashwini* is high yielding with short duration (105 days) produced elliptical long tubers of dark purple colour. The other varieties *Sree Bhadra*, *Sree Vardhini*, *IB-9011-1*, *IB-9015-9, IB-700* are relatively stable under climatic fluctuations. The performance of *Kamal Sundari*, *Varsha*, *Rajendra Sakarkand* under aberrant coastal climate was satisfactory (Haldavnekar 2005).

The lesser yam variety *Konkan Kanchan*, *Sree Lata* perform better under the coastal agro climatic conditions. *Konkan Kanchan* is ready for harvesting within 7 months whereas *Sree Lata* takes 8 months. *Sree kartika* variety of greater yam takes 6 months for harvesting with high yield of 29.29 t ha^{-1} under coastal climatic conditions. The greater yam variety "Konkan Ghorkand" released by DBSKKV, Dapoli for Konkan region is an erect climber which produces spherical snow white tubers with purple tinge andagreeable tase with a yield of 16 t ha^{-1} (Mhaskar 2013a).

The *Konkan Kalika* variety of Aerial yam produced superior yield of 5.27 t ha^{-1} with uniform, round shape and black colour bulbs under coastal Maharashtra condition (Anonymous 2015). The edible aroids cultivated in coastal region include elephant foot yam, xanthosoma, colocasia and alocasia showed better sustenance under coastal agroclimate. The *Konkan Haritparni* variety of xanthosoma has erect pattern of growth and produced dark green leaves with purple tinge preferred in market for roll preparations (Mhaskar *et al.* 2016). The colocasia variety *Kaka Kachu, Sahasra Mukhi, Kovvur* registered high yield under coastal conditions. The performance of elephant foot yam variety *Gajendra* was superior for yield performance (26 t ha^{-1}) in comparison with other varieties (Anonynous 2016).

The performance of Kamala Sundari, Varsha, Rajendra Sakarkand under abberant Coastal climate was satisfactory (Haldavnekar 2005). Leaf area, yield of tubers per vine, biological yield, weight of vine and carotin content expressed maximum phenotypic as well as genotypic variance in these sweet potato cultivars.

Production protocol

In elephant foot yam corms of 500 g planted at 75 x 75 cm produced highest tuber yield, net returns and benefit: cost ratio (Mhaskar *et al.* 2016). In cassava, spacing of 90 x 90 cm and fertilizer dose of 100 kg N, 50 kg P and 100 kg K ha^{-1} was found optimum in coastal Maharashtra. Spacing modifies size of tuber and yield of lesser yam. The distance of 60 x 30 cm exhibited the maximum yield (31.29 t ha^{-1}) but planting at 90 x 30 cm resulted in maximum production of bold tubers (8.43 t ha^{-1}) (Table 1). The medium (100-200 g), small (50-100 g) and very small (<50 g) yam produced were maximum at 60 x 30 cm spacing. Planting of lesser yam at spacing of 90 x 30 cm was advantageous in coastal region for obtaining higher net returns (Table 1) (Anonymous 2014a).

Appropriate nutrient management

In sweet potato, application of 100 kg N ha^{-1} increased the vegetative growth, weight of tuber and plant per ha^{-1}, number of tubers, length and girth of tuber, whereas 75 kg N ha^{-1} contributed maximum total sugar, reducing sugar, non-reducing sugar and starch content without affecting the fibre content in tuber. The application of 75 kg K ha^{-1} had maximum yield per plant and hectare, total

Table 1. Effect of spacing on partitioning tuber yield of lesser yam.

Spacing (cm)	Tuber yield (t ha^{-1})				
	Bold	Medium	Small	Very Small	Pooled mean
90 x 90	5.33	4.47	2.83	1.02	13.66
90 x 60	7.55	7.31	3.49	1.21	19.55
90 x 30	8.43	10.43	6.15	2.16	27.17
60 x 60	5.93	8.37	5.30	1.83	21.43
60 x 45	7.66	8.90	6.41	1.90	24.87
60 x 30	6.91	12.61	8.70	3.07	31.29
SE m ±	0.25	0.31	0.16	0.09	0.43
CD@ 5%	0.77	0.95	0.51	0.29	1.35

Source: Anonymous 2014a; Note: Bold > 200 g, 100 g < Medium > 200 g, 50 g < Small > 100 g, 50g < Very small.

sugars, reducing sugars, non-reducing sugars and starch content in sweet potato whereas 50 kg K ha^{-1} produced maximum protein in tubers (Rizvi 1982). Crop rotation of vegetable cowpea and sweet potato was an ideal crop sequence to generate a net income of ₹ 25000 ha^{-1}. Rainfed sweet potato was a good intercrop in juvenile cashew orchard (Mhaskar *et al.* 2016).

For integrated nutrient management in cassava, green manuring with dhaincha (*Sesbania rostrata)* seeds @ 20 kg ha^{-1} with application of 7.5 t FYM, 75 kg N, 50 kg P, 75 kg K ha^{-1} and use of 3 % *panchagavya* was beneficial under coastal conditions for obtaining higher net returns and maintaining the soil healt (Anonymous 2012) (Table 2) whereas use of 10 t FYM ha^{-1} and 80:30:40 kg N:P:K fertilizers ha^{-1} with 90 x 60 cm spacing achieved the highest net return and benefit:cost (B:C) ratio of lesser yam (Mhaskar *et al.* 2016).

Canopy Management of vines

Under changing climatic conditions, for improving size of bulbils, thinning and pruning of bulbs of aerial yam was advantageous. Retention of 10 bulbs and pruning the vine thereafter, improved the marketable yield of the produce to ~5 t ha^{-1} in contrast to the unmanaged vines which yielded @ 4.33 t ha^{-1} (Table 3). However, retention of 5 bulbs per vine though improved individual bulb size (58 g) resulted in reduction of total marketable yield (Anonymous 2013a).

Proper harvesting and storage

In sweet potato, use of produce viz. culinary and industrial determines exact harvesting stage. The tubers of variety *X-5, V-35, Collection-43, Collection-71* and *Pen local* should be gathered after 135 days of planting for culinary purpose. For extraction of starch, sweet

Table 2. Effect of integrated nutrient management on growth, yield attributes, yield and economics of Cassava (Pooled mean 4 years).

Treatment	Growth and yield attributes				Tuber yield (t ha^{-1})	Economics	
	Height (cm)	Fresh biomass (t ha^{-1})	Tuber yield (kg $plant^{-1}$)	Av. tuber wt. (g)		Net Return (₹ ha^{-1})	B:C ratio
RDF+P	171.33	22.70	2.73	405.29	38.17	72,879	1.70
3/4th RD FYM&N&K+D+P	183.11	23.78	2.87	413.76	42.43	90,462	1.88
3/4th RD FYM&N&K+G+P	182.89	23.19	2.91	441.41	45.67	90,154	1.77
FYM	120.56	10.20	1.14	274.23	27.78	37,307	1.38
Control	99.44	6.14	0.55	208.52	16.52	26,826	1.42
CD (0.05)	13.57	2.63	0.33	37.82	3.46	--	--

Source: Anonymous 2012; P = Panchagavya, D = Dhaincha, G = Glyricidia, RDF = Recommended dose of fertilizer.

Table 3. Effect of thinning of bulbs and pruning of vine on marketable yield and average weight of marketable aerial bulb.

Treatment	Pooled mean of three years					
	With pruning			Without pruning		
	Marketable Aerial Bulb Yield (t ha^{-1})	Total Marketable Yield (t ha^{-1})	Av. Wt. of Marketable Aerial Bulb (g)	Marketable Aerial Bulb Yield (t ha^{-1})	Total Marketable Yield (t ha^{-1})	Av. Wt. of Marketable Aerial Bulb (g)
Retain 5 bulbs	2.70	4.18	58	2.40	3.46	51
Retain 10 bulbs	3.40	5.05	41	3.02	4.33	37
Retain 15 bulbs	2.51	3.88	25	2.26	3.37	25
Mean	2.87	4.37	41	2.56	3.72	38
Control			-		4.36	28

Source: Anonymous 2013a; Control = no thinning of bulbs and no prunning.

potato should be harvested after 150 days of planting as the starch content markedly increases till then. Varieties *Co-3*, *Kalmegh*, *Collection-71* and *Pen local* were better suited for starch extraction (Deshpande 1986). The variety*75 OP/9* harvested after 105 days of planting whereas the variety *Co-3, Kalmegh* and *S-30* should be picked at 120 days of planting (Deshpande 1986). The variety *H-268* should be harvested after 120 days but before 135 days of planting.

Under aberrant climate of coastal Maharashtra, the variety *Kamal Sundari* was found excellent for all organoleptic characters and recorded the highest average organoleptic score (7.76) followed by *Konkan Ashwini* (7.08) (Table 4) (Mhaskar *et al.* 2013b).

The cold storage was the best storage method for sweet potato, which imparted maximum shelf-life (45 days), minimum PLW (15.84 per cent) and lower sprouting (37.08 per cent) of tubers at the end of storage period (Sable 2005). Use of Maleic hydrazide (1000 ppm) was effective in controlling sprouting during storage at ambient temperature as compared to control. Among the varieties tested, *Konkan Ashwini* had minimum sprouting at the end of storage period. However, the higher level of Maleic hydrazide and Cycocel produced the reduction in the vegetative growth of sweet potato varieties. The moisture content and reducing sugar was 79 % and 2 % at 45 days after planting which showed a decline upto 66 % and 1 % respectively at 120 days after planting. the total soluble solids, acidity, pH and total sugar boosted from 45 days to 120 days after planting. The chemical composition including total soluble solids, acidity, pH and total sugar of sweet potato tuber was 4.24 ºB, 0.039 %, 5.97; 5.62 % respectively at 120 days after planting (Shirke 2000).

Plant Protection

Under climatic vagaries, sweet potato is severely damaged by sweet potato weevil which is considered its major pest resulting in huge economic loss. Root knot nematode and snails were also observed as a minor pest in some tuber crops. Anthracnose on greater yam and leaf spot of sweet potato are common diseases aggravate in changing climate in Konkan, Maharashtra (Table 5 and 6). Planting of sweet potato and marigold in of 2:1 proportion rows or band placement of *Beauveria bassiana* @ 6.75 kg ha^{-1} in soil, one month after planting is advantageous for effective management of sweet potato weevil. Growing of yam bean as a border crop 15 days before planting of elephant foot yam and spraying of yam bean seed extract + soapnut water extract @ 50 ml each per litre of water as prophylactic spray is useful for control of snails. Planting of marigold between two rows of lesser yam or application of neem cake @ 100 g pit^{-1} at the time of planting is beneficial for the management of root knot nematode in lesser yam.

Table 4. Organoleptic evaluation of the sweet potato entries

Entry	Organoleptic Score			
	Colour	Flavour	Texture	Average Score
Konkan Ashwini	7.08	6.75	7.42	7.08
CIPSWA-2	6.42	6.88	5.88	6.39
Kamala Sundari	7.58	7.71	8.00	7.76
362/7	5.08	5.58	5.42	5.46
SV-98	5.38	5.83	5.25	5.49

Source: Mhaskar *et al.* 2013.

Conclusion

The tuber crops (viz. sweet potato, greater yam, lesser yam, elephant foot yam, xanthosoma, aerial yam and cassava) are grown successfully under coastal climatic conditions in Maharashtra. The production technology pertaining to varietal development, planting protocol, judicious nutrient management, appropriate maturity and harvesting are useful for the sustainable production of tuber crops under coastal agroclimatic condition even under climatic aberration.

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Table 5. Major pests and their control measures for the tuber crops.

Crop	Pest	Sub-heading	Details
Sweet potato	*S*weet potato weevil *Cylas formicarius* (Fab.)	Biology	• Female deposited on an average 145.52 eggs. The incubation period ranged from 6-9 days with hatching percentage of 93.60. Five instars of grub were completed with an average period of 4.31, 4.66, 5.6, 5.08 and 5.4 days, respectively. Total grub period was completed with an average of 25.24 days. Pupation occurred in pupal chamber and lasted for a period of 3-5 days. The sex ratio was 1.03:1.00. The mean developmental period from oviposition to adult emergence averaged 36.26 days.
			• The longest mean total developmental period was noticed in *DR-56* (39.20 ± 2.59 days) with a minimum mean developmental period (32.60 ± 1.14 days) in cultivar *AINSHET.*
		Management	• Varieties *V-35, S-30, X-24 C-71* Pen local *S-43, O.P/59* and *S-73* if, harvested at 105 days after planting reduce the weevil damage.
			• Granular insecticides phorate 10 G @ 1 Kg ai ha^{-1} and carbofuran 3G @ 1 Kg ai ha^{-1} were highly effective over drenching treatments of fenthion, aldrin, endosulfan and quinalphos @ 0.05 per cent concentration.
			• IPM components *viz.*use of healthy cuttings for planting, dipping of cuttings in 0.1 per cent carbaryl before planting, mulching with paddy straw and earthing up at 30 and 60 days after planting and use of sex pheromone trap were superior over rest of the treatments with 14.28 per cent tuber damage and yield 15.55 t ha^{-1}.
			• Paired rows of sweet potato and one row of marigold observed to be the most economical treatment, with 1:1.73 B.C.
			• The treatment of application of *Beauveriabassiana* and neem cake were effective in reducing tuber damage and number of weevils emerged from tubers.
			• Application of neem cake at the time of planting recorded 87.50 per cent tubers free from weevil infestation followed by treatments *Beauvereabassiana* (78.57%), barrier crop-Marigold (78.31%) and *Metarhizium anisopliae* (77.33%).
		Screening	• None of the twenty six varieties screened were found to be immune.
			• Cultivar *AINSHET* recorded lowest crown infestation (13.33%) and tuber infestation (15.15 %) while cultivar *No. 440038* recorded highest (73.33%) crown infestation. The cultivar *S-30* had highest (95.31%) tuber infestation.
Lesser Yam	Root-knot nematode *Meloidoyne incognita*	Management	• Application of Carbofuran 3 G, 50 gm pit^{-1} and neem cake @ 100 gm pit^{-1} at time of planting were observed to be equally effective.
Elephant Foot Yam	Snails	Management	• Yam bean as a border crop was significantly superior over rest of the treatments in keeping snails away from the crop. The next best treatment was yam bean + soap nut water extract as a spray.

Source: Ahire 1998, Deogharkar 2015, Kadam 1986, Anonymous 2011, Anonymous 2013b, Anonymous 2014b, Karmarkar 2008.

Table 6. Major diseases of tuber crops and their control measures.

Crop	Disease	Sub-heading	Details
Sweet potato	Leaf spot of *S*weet potato *(Curvularia lunata)*	Management	• Mancozeb (0.2%) was the best fungicide inhibiting the growth of *Curvulari alunata* followed by Mancozeb + carbendazim and Tricyclazole. • The bulb extract of *Allium sativum*at 10.00 % concentration was most effective (66.64) in inhibiting the mycelia growth of the pathogen followed by Neem (63.84) and Tulsi (59.57). *In vivo* studies (Pot trial) confirmed the same.
		Screening	• The varieties viz., *Amroli Local, Durshet Khandala* and *Nante Red* were immune to the leaf spot disease, while the varieties *85/168, IB – 700, S-72* were resistant to the leaf spot.
Sweet potato	*Fusarium roseum* L.	Management	• Under *in vitro* conditions, Carbendazim (0.1 %), Bordeaux mixture (1 %), Copper oxychloride (0.2 %), Thiophanate methyl (0.2 %) and Hexaconazole (0.1 %) were found effective against *Fusarium roseum.*
		Screening	• *Varsha, S-27* and *IB.90.15.9*. varieties were resistant to *Fusarium roseum.*
Greater Yam	Anthracnose (*Colletotrichum gloeosporioides*)	Management	• Bordeaux mixture (1%), Copper oxychloride (0.25%), Carbendazim (0.15%) and Thiophanate methyl (0.15%) were very effective against *Colletotrichum gloeosporioides.* The bioagents *viz. Trichoderma virid and, T. Harzianum* were also effective. The extract of garlic (10%) was very effective against the disease.
		Screening	• *IGDA-1, DA-210, Sree roopa, DA-25, DA-168* and *DA-215* were found moderately susceptible.

Source: Thengne 2002, Mishra and Dixit 1977, Patil 2003, Sinha and Mishra 1974, Pawar 2006, Gadre and Mandokhot 1989

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