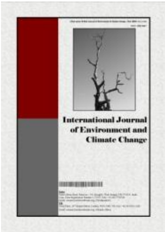

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Sustainable Production of Barnyard Millet through Improved Production Technologies

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Authors' contributions

This work was carried out in collaboration with all the authors. Author TSS collected literature and wrote the manuscript. Author s CC, TEN, HSL and DCH has gone through the article critically and gave suggestions for improvement. All authors have read and approved the final manuscript.

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ABSTRACT

Barnyard millet is cultivated for food besides fodder. Millets are less nutrient demanding, cultivated with low chemical inputs, less greenhouse gasses emitting crop thus millets reduce carbon footprint in agriculture. In India, barnyard millet is a significant dry land crop and cultivated over an extensive range of environmental situations under deprived soil conditions for human consumption and for fodder as well. It has the distinct feature of drought resistance and can survive water logging for two weeks which are unique features of it. Crop has wide flexibility and lodges a special place in marginal rainfed areas because of its short life cycle. In India, it is largely cultivated in two different agro-ecologies i.e., in the mid hills of Himalayan region of Uttarakhand in the North and Deccan plateau region of southern peninsula of India. Less productivity of crop is largely due to

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poor crop management practices. Barnyard millet is considered of regional importance and hence little attention is been given for research despite its higher significance. Considering the significance of the crop, an initiative has been undertaken to draw out the agronomic management strategies for barnyard millet for sustained productivity and to compile the agronomic studies on the crop.

Keywords: Millet; yield; fodder; dry land; climate and sustainability.

1. INTRODUCTION

Millets can grow under drought conditions; they can withstand higher heat resistance also grown under non-irrigated fields and in low rainfall area. We can get good yield even under water deficient condition too. Millets are staple food in some part of Karnataka [1]. Millets are members of the Poaceaceae family (Panicum, Setaria, Echinochloa, Pennesetum and Eleusine). Proso millet (*Panicum miliaceum*), foxtail millet (*Setaria italica*), Japanese barnyard millet (*Echinochloa frumentacea*), finger millet (*Eleusine coracana*), kodo millet (*Paspalum scrobiculatum*), and brown top millet (*Panicum ramosa*) are some of the millets [2]. Millets are having nutritional and health benefits and also help in managing health problems like diabetes mellitus, hyperlipidemia, etc [3]. When compared to cereals, millets offer a higher nutritional quality. Finger millet has a lesser protein and fat than other millet varieties. Millet has a higher mineral concentration than rice. Iron and phosphorus are abundant in them. Finger millet has the greatest calcium concentration of all the millets. The B complex vitamins are found in the grain's outer bran layer. When compared to rice and wheat, millets have a somewhat higher level of antinutritive elements. However, these antinutritional factors are phytochemicals resultant from plants that have therapeutic properties and are thus indicated for a variety of degenerative disorders such as diabetes and hypertension [4]. Farmers are reviving cultivation of barnyard millet, minor millet which can be grown on low fertile soils with limited water.

The grains are appreciated for the high nutritional value and lower cost of production as related to cereals in addition to the agronomic advantages. Millet cultivation areas have shrunk over the 5 decades and all millet growing areas have moved towards other crops reasons being availability of alternative crops with attractive market price like rice and pulse crops and lack of supporting measures. Barnyard millet is one important *kharif* crop of Uttarakhand and grown under rainfed condition in hills up to a higher of 2700 m from sea level and is commonly seen in slope of hilly areas and undulating fields of hilly, marginal, or tribal areas, where barely any alternatives exist for crop enhancement. Barnyard millet is considered of regional importance and hence little attention is been given for research despite its higher significance. Barnyard millet being quick durated can grow in hostile environmental conditions with virtually not or very less input and can withstand various stresses *i.e*., biotic and abiotic.

2. CLIMATE RESILIENT CROP

The *Echinochloa* species generally has likely resistance against various abiotic and biotic stresses. Though, cultivated species such as *E. esculenta* and *E. frumentacea* are widely vulnerable by pest and diseases (i.e., shoot fly, stem borer, grain smut, and loose smut) at different development stages of the crop [5,6] and have a high grade of tolerance to innumerable abiotic stresses [7]. Similarly, these are also the required choice of farmers for cultivation in various adverse environments *i.e*., prone to drought or flooding and these features clearly indicate us the possibility of having some specialized rhizosphere organizations which can enable the uptake and release of oxygen from their roots at traumatic conditions.

Indian agriculture is highly reliant on the spatial and temporal distribution of monsoon rainfall [8]. Existence and successful reproduction in a stressful environment are a complex phenomenon and plant survival in stressful environments has a physiological cost [9], which becomes a major limitation for growth and development and can reduce yield by 50% in major crops [10].

The *Echinochloa* species usually has possible resistance against various abiotic and biotic stresses. The cultivated species such as *E. esculenta* and *E. frumentacea* have a high tolerance to various abiotic stresses. Indian agriculture is highly reliant on monsoon rainfall. During the present era, climate change is an important concern and barnyard millet can be chosen under this situation, as eco-friendly crops which also can withstand adverse impacts of global warming and climate variation as well. Barnyard millet has been familiar in Australia as a quick rotation crop foraging during spring and early summer. In Australia, this crop is used as a short-term rotation crop for spring–early summer grazing, and its fast-early growth can help to meet the feed shortages in early summer following floods or drought.

3. BARNYARD MILLET AS A FODDER CROP

Millets have relatively a lower position in India, among feed crops in agriculture, but are very vital from food security point at regional and farm level. Frequent fluctuations in temperature and indeterminate precipitation limit productivity and cause injury of diversity. Barnyard millet is also being a vital source of fodder as leaves are wide, and the plant picks up in short time producing voluminous fodder which is extremely palatable and used for production of hay or silage. Crop can produce as many as eight harvests per year owed to fast growth and early maturity. Under Indian circumstances, the average dry fodder of barnyard millets is 6 tons/ha [11]. Barnyard millet fodder pays 11.5% of the total fodder consumption of the in Uttarakhand and the recommended fertilizer application pointedly increases the fodder yield [12] and barnyard millet was found good under fodder cutting management for dual purpose use [13].

4. SIGNIFICANCE OF IMPROVED VARIETIES IN BARNYARD MILLET

Growth and yield characteristics of genotypes depend on genetic and environmental factors. The varieties producing higher amount of dry matter, use greater quantities of nutrients from soil. The various root characteristics might also differ with the varieties which may affect nutrient uptake. In crop production systems, crop genotypes play a dominant role. For successful crop production, knowledge of varietal morphological and physiological characteristics is necessary.

5. ROLE OF SOWING WINDOWS AND ESTABLISHMENT TECHNIQUE

Timely sowing of crops commonly safeguards adequate time for root growth and vegetative growth for optimum harvesting of available soil nutrients and radiant energy. During 1986-87 at Dholi, sowing barnyard millet with the onset of monsoon while at hilly region of Ranichauri, Uttarakhand, sowing by 1st week of May was found as finest for obtain higher yield further delay has drastically reduced the yield. Further, dry sowing a week in advance to probability of receiving 75 % dependable rains along with 125 % of recommended population gave higher grain yield [15 & 16]. Sowing during first fortnight of July was found ideal at Dindori, Jagadalpur and Vizianagaram while for Athiyandal, 1st fortnight of September day 1 to day 15 was found optimum for barnyard millet [17,11]. Transplanting at 35 cm x10 cm with 125 % recommended dose of fertilizer F [18] could be adopted under sodic soil condition to achieve higher grain yield in barnyard millet. Whereas, 25 cm x 10 cm plant to plant and 3-4 cm depth of sowing is commonly recommended for barnyard millet [19]. Further dry sowing a week in advance to probability of receiving 75 percent dependable rains along with 125 percent of recommended population gave higher grain yield (2.1 tons/ha) compared to other treatments (Table 2) [20].

6. NUTRIENT MANAGEMENT

In spite of the element that barnyard millet has a lower requirement, recent cultivars respond well to extra nutrients. For integrated nutrient management, a general recommendation of 5-10 t FYM per hectare is appropriate based on the fertility status of soil. For Bihar, Tamil Nadu, and Uttar Pradesh, the recommended fertilizer doses (N- P_20_5-K_2O) are 40-20-0; however, for Andhra Pradesh and other states, 20:20:0 is recommended [19]. In India, optimum nutrient management has played a major role in realizing the massive increase in food grain production. At Ranichauri, Uttarakhad, application of P in superphosphate and rock phosphate form in 50:50 proportion and treating seed either with *Agrobacterium radiobacteror* with *Aspergillus awamori* gave higher yield during 1998.The split application [21] of 150 % of RDF 99:49.5:30 NPK kg ha^{-1} (NK: 25% Basal, 75% in equal split at tillering & flowering) and transplanting at 35 cm x 10 cm with 125 % RDF recorded extra grain yield with higher growth and yield attributes [18].

Foliar application is effective technique that could be effective for 6-20 times more than soil application. Growth and yield traits were significantly influenced by foliar nutrition and fertilizer application [22] and RDF +FYM +Vermi

Table 1. Varieties recommended for diverse agro climatic zones

Name of variety	Institute where developed	Year of release	Grain yield (tons/ha)	Area of adaptation	Special features
Kanchan	CSAUA&T, Kanpur	1993	1.5-1.8	Uttar Pradesh	Resistant to grain smut
VLMadira 172	VPKAS, Almora	2000	2.1-2.3	Uttar Pradesh, Gujarat and Karnataka	Resistant to grain smut
Sushrutha (RAU 11)	RAU, Pusa and UAS, Dharwad	2000	2.0-2.2	Karnataka	High grain yield
VL Madira 181	VPKAS, Almora	2001	1.6-1.7	Bihar, Karnataka, Madhya Pradesh, Tamil Nadu	Profuse tillering
CO(KV) 2	TNAU, Coimbatore	2008	2.1-2.2	Tamil Nadu state	Non-lodging, profuse tillering, and suitable for contingency planting.
DHBM 93-3	ARS, Hanumanmatti, UAS, Dharwad	2016	2.2-2.4	National	Responsive to fertilizer application
DHB-93-2	ARS, Hanumanmatti, UAS, Dharwad	2018	Grain yield: 2.76 t/ha and Fodder yield: 6.19 t/ha	Recommended for cultivation in Agro-climatic Zone -3 and 8 of Karnataka state	Variety suitable for contingency planting.
MDU-1	Agricultural college & Research Institute, TNAU, Madurai	2018	Grain yield of 1.5-1.7 t/ha (Rainfed) and 2.2-2.5 t/ha (Irrigated)Fodder yield of 3.0-3.3 t/ha	Suitable for southern districts of Tamil Nadu	Suitable for *kharif*, *rabi* and summer seasons throughout Tamil Nadu No-shattering, High milling percentage (70 %)
DHBM-23-3	ARS, Hanumanmatti, UAS, Dharwad	2019	2.0-2.1	Andra Pradesh, Karnataka, Madhya Pradesh and Tamil Nadu	High grain and fodder yield, Suitable to rainfed condition in *Kharif.*

[Source: 14]

Table 2. Barnyard millet yield as influenced by different agronomic manipulations to mitigate climate change

Treatments	Yield (tons /ha)									
	2010		2011		2012				Mean over years	
	Grain	Straw	Grain	Straw	Grain	Straw	Net monetary returns (Rs./ha)	Benefit: cost Ratio	Grain	Straw
S1: Dry sowing based on the probability of receiving dependable rains at 75%	2.036	5.291	1.827	3.050	2.017	6.938	16693	1.81	1.960	5.093
S2: Sowing after receipt of rains	1.950	5.207	1.954	3.167	1.850	6.383	13633	1.67	1.918	4.919
S3: S1+With thinning and maintaining 125 % of regular population	2.075	5.369	2.104	3.183	2.128	7.770	20874	2.02	2.102	5.441
S4: S1+With thinning and maintaining 150 % of regular population	1.975	5.233	1.754	3.017	1.480	6.160	7860	1.38	1.736	4.803
S5: S2+With thinning and maintaining 125 % of regular population	2.035	5.179	1.803	3.000	1.462	5.828	7258	1.35	1.767	4.669
S6: S2+With thinning and maintaining 150 % of regular population	1.806	5.157	1.403	2.633	1.388	5.690	6010	1.29	1.532	4.493
S.Em±	0.054	0.057	0.0215	0.332	0.044	0.253	-	-	-	-
CD(P=0.05)	0.170	0.181	0.679	1.048	0.142	0.797	-	-	-	-

[Source: 20]

compost along with foliar application of 0.5% ZnS04 + 1% Urea recorded higher growth and yield attributes. Organic and inorganic combination followed by the application of inorganic [23].

7. WEED AND WATER MANAGEMENT

Either spraying of 2, 4-D Na salt @ 1.00 kg a.i./ha as post emergence or hand weeding was found better was emerged from the studies of 1991-93 conducted at Ranichauri however, Express at 10 g ai/ha was effective in controlling weeds besides resulting in higher yield [23] followed by 2,4-D Na salt at 1.0 kg i/ha and both are comparable to hand weeding twice. Isoproturon can be successfully used in areas where cultural practice of hand weeding is not possible [24,25] further maintaining weed free during crop growth period was found better in getting higher grain yield followed by providing weed free for first 35 days from sowing. Barnyard millet being a rainfed crop and does not need irrigation if sown at optimum time during *kharif* season. If the dry spell extended for longer time due to intermittent drought, supplementary or protective irrigation can be given at critical stages of crop i.e., tillering and panicle initiation (45-50 days after showing).

8. CROPPING SYSTEM

Intercropping of either barnyard millet + horse gram or barnyard millet + rice bean/Niger was better inter cropping system [26-30] and barnyard millet+ rice bean (4:1) under rainfed conditions produced higher grain yield in intercropping system with 50 per cent N. Crop mixtures of barnyard millet 90% and soybean 10% was found feasible system. The next best is found to be the mixed cropping of barnyard millet with amaranths (90:10 by weight). The pooled data over multi location (2017-20) at AICRP on small millets suggested that barnyard millet + Red gram (6:1) was the utmost remunerative intercropping system for increased overall productivity of the system.

A study on intercropping of amaranth crop in barnyard millet to know the optimum spatial ratio was carried out at Ranichauri during 2017. When barnyard millet was intercropped with amaranthus, the Barnyard millet grain equivalent yield(2308 kg/ha) and Benefit cost ratio (3.02) was significantly higher than in other treatments. The next best treatment was found to be the mixed cropping of barnyard millet with amaranths (90:10 by weight) [20].

9. WAY FORWARD

The agronomy of crop and cropping pattern is situational and regional specific on some issues, hence has to be evaluated for natural resource management. Precise input management to achieve potential yield approach needs more emphasis. As the crop is having climate-resilience, its potential can be harnessed by concentrated research efforts. Finally, joint efforts under single umbrella on public awareness about nutritional value, research on diversified issues related with crop production, value addition, processing and utilization and government provision for large marketing might save the crop.

10. CONCLUSION

The concept of cropping systems in India is as old as agriculture. Less productivity of crop is mostly due to inadequate knowledge on high yielding varieties, planting density and nutrition, high weed infestation, disease and insect pest incidence. As a short duration crop with tolerance to abiotic extremes, barnyard millet can be a suitable crop in intensive sequential cropping system. Barnyard millet can be considered a climate smart crop in the current climate change context owing its brief crop sequence and capability to grow on a extensive range of soil types.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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