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Management of Finger Millet based Cropping Systems for Sustainable Production

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A B S T R A C T

Finger millet is an important nutritive crop of the semi-arid zones of the world and it is the staple food crops for millions of people in Africa and Asia. To achieve more sustainable production from finger millet based cropping systems intercropping and sequential cropping of finger millet with pulse and oil seeds proved better and recorded more system yield per unit area than sole cropping of finger millet. Among the different finger mill based cropping systems finger millet + legumes recorded more sustainable yield and less weeds, insects and diseases infestation in the crop. Also reported, that including legume and oilseeds in finger millet based cropping systems reduced fertilizer, herbicides, insecticides application in crop than sole cropping. It is proven that combine use of cultural, mechanical, chemical and biological management practices of crop cultivation recorded more yield per unit area, less cost of cultivation than sole cropping of finger millet.

Introduction

Finger millet (*Eleusine coracana* (L) Gaertn.) belongs to family Poaceae commonly known as ragi, mandua, nagli, kapai and madua is widely cultivated in India. According to DeCondolle (1886) mandua probably originated in India, as many of the forms exist in the country. Chromosome number of finger millet is 2n = 4x = 36. It might have originated from *Eleusine indica L.* a grass that occurs in many parts of northern India. The common name finger millet is derived from the finger like branching of the panicle.Finger millet was domesticated from Ethiopia and Uganda 5000 years ago and it was reached in India 3000 years ago reported by Dida *et al.*, (2008). Globally it is fourth most important crop after sorghum, pearl millet, and foxtail millet. It is grown globally on over 4 million hectares area and in India it is cultivated over an area of 1.138 million ha with a total

production of about 1.68 million tones and 1483 kg^{-1}productivity (Anon, 2014). It is an important crop of Karnataka with >60% area of the country followed by Uttarakhand (10%), Maharashtra (9.6%), TamilNadu (6.5%), Odisha (4.8%) and Andhra Pradesh (3.6%). It is mainly a Kharif season crop, but also grown during *Rabi/summer* in Karnataka and Odisha over a smaller area. In India, it observed that area and production of finger millet has decreased this might be due to the increased area under maize and maize-based cropping systems. Among the different states of India Karnataka has the first rank in both area and production in the country. TamilNadu state has recorded highest productivity of finger millet followed by Karnataka which is above the national average yield. It is mainly a *Kharif* season crop, but also grown during *Rabi/summer* in Karnataka and Odisha over a smaller area. It is a staple food crop in Karnataka and some hilly regions of the country and also a staple diet of major of south regions of Karnataka, especially in the rural areas. The crop has the wider adaptability to different soils from poor to high fertile soils. It can also tolerate a certain degree of alkalinity. Munns and Tester (2008) reported that finger millet crop plant can grow under saline soil condition. Babu *et al*., (2013) also evaluated that finger millet are tolerance to a wide range of biotic and abiotic stress. According to Directorate of Millets Development the most suitable soils for finger millet are alluvial, loamy and sandy soils with good drainage.

Importance of finger millet

Among the major food grains, finger millet is one of the most nutritious crops for protein, minerals (calcium and iron) and provides 8-10 times more calcium than wheat or rice Anon (2014). Finger millet is a nutritive crop which provides protein, carbohydrates and minerals but among the different cereals and millet, it contents very rich amount of calcium and carbohydrate of finger millet reported having the unique property of slower digestibility thereby it is a very good food crop for pregnant women and person who suffering from diabetes because Watt and Breyer-Brandwijk (1962) reported that finger millet have been used to remedy several diseases.

The green straw of finger millet is suitable for making silage, which is sweet smelling and consumed by cattle without any wastage. It is an eco-friendly crop, good for organic agriculture and requires less nutrients as compared to many other cereals. Munns and Tester (2008) reported that finger millet straw is a highly nutritious fodder for the animal due to its nutritional richness.

Finger millet can be cultivated in a wide range of climate and soil conditions and require very less water throughout the growth period so it is a possible alternative crop in the events of natural calamities like drought and flood. It is short to medium duration varieties fit for contingency crop planning to mitigate drought it is mainly because of their earliness, low water requirement and high drought tolerance. Hegde and Gowda (1986) also grouped finger millet varieties such as early maturity (90–100 days) and late maturity (110–120 days).

When favorable conditions return after alleviation of stress the small millets especially finger millet recuperates fast and grow luxuriantly and also reported that it can be grown a wide range of climate condition and even under very low moisture situation it can grow well and produce yield because ofit drought tolerance. To nourish the astronomically increasing world population not only need to increase food grain production but also there is need to maintain sustainability in the production this can be achieved in future by combine use of all

management practices for finger millet production. Rurinda *et al.,* (2014) reported that it provide food security to poor people's.

How can we achieve sustainable production from finger millet based cropping systems

Growing of only cereals is not so much remunerative in the present scenario of agriculture to fulfill the diverse demand of consumers and rapidly growing population. It is an urgent demand of incorporation of the pulse, oilseed cereals and in millet based cropping system. Babalad (1999) also reported that integrated nutrient management is very effective to maintain sustainable productivity for a longer time. Intercropping of finger millet with different pulses and oilseeds has greater scope to utilize the land and other resources to the maximum extent. The productivity of the system can be enhanced by a judicious selection of intercrop differing in duration and growth alone in many situations. Sarker and Pal (2004) reported intercrops duration and spatial arrangement significantly affect the productivity of the component crop. There may negative or positive effect on component crop because it depends on plant population of both the crop in intercropping system. If crop production is totally chemical intensive or intensive use of herbicides, insecticide and other pesticides in crop management may able to produce more production per unit area per unit time but this is capable only for short period of time and by using these practices cannot maintain good quality agricultural food products and sustainability in crop production.

Because of some disadvantage of chemical intensive cultivation such as there is decreased the quality of the food products, develop resistance in different insects, diseases, and weeds, environment pollution, reduce biodiversity, land degradation mainly due to the chemically intensive cultivation. Hemalatha and Chellamuthu (2013) also reported that continuous use of inorganic fertilizer alone reduced the soil organic carbon level. Thereby to achieve more sustainable production from finger millet based cropping systems is possibly by efficient cropping system management with optimum utilization of natural resources. Anil Kumar *et al*., (2003) also reported that for achieving sustainability in production need to conjunctive use of inorganic fertilizer, organic manures, and biofertilizers. Sustainable production for a long period of time from different crop based cropping systems possible by making complementary interaction between the crop in cropping system like including legumes in cereal-based cropping system, deep-rooted crop in shallow rooted crop based cropping systems, optimum population of both the crops, combine use of agronomical/ cultural, mechanical, chemical and biological approaches to weeds and pest management. To achieve sustainable production in term of ecological, economical and biological sustainability from finger millet based cropping systems following approach can follow on farmer field. Wu and Ma (2015) and Chen *et al*., (2011) also reported that integrated nutrient management have pivotal role sustainable production and food security.

Finger millet based cropping systems in India

Finger millet

Finger millet is very fit crop for different cropping systems such as intercropping sequential cropping, strip cropping, mixed cropping crop rotation etc. Thereby it can be growin any type of cropping system but commonly grown as a sole crop and mixed crop with pulses and oilseeds. It can be sown as transplant or broadcast but yield is higher

when it transplant with definite row proportion because of uniform distribution of light and other require resources in among the crops in cropping system.

Intercropping systems

According to annual report of directorate of small millet on finger millets indicated the major finger millet based cropping system follow in India as finger millet + pigeon pea in 8-10: 2 or finger millet + field bean in 8: 1 for Karnataka; Tamil Nadu and finger millet+ field bean in 6: 2 row proportion for Bihar; finger millet + soybean (90:10 crop mixtures) for Gadhwal region of Uttarakhand and Finger millet + moth bean /black gram (4:1) for Kolhapur. Maitra *et al*., (2000) reported that finger millet produced more yield under intercropping with pigeon pea and groundnut compare to grown as sole cropping.

Rotations/sequence cropping

Finger millet crop rotations with legumes or oilseeds and the relay cropping are the important practices to achieve sustainability in crop production. Some major finger millet based crop rotations or sequential cropping such as rotation with legumes like green gram/ black gram. Rice bean/soybean for northern regions of India and horse gram/pigeon pea/ground nut for southern states of India. Similarly other dominant finger millet based sequential system following in India such as Ragi – Mustard, Ragi – Barley, Ragi – Linseed, Ragi – tobacco and Ragi – Gram in north India and Ragi - Potato – Maize, Ragi - Potato – Ragi, Ragi – Groundnut, Ragi – Sugarcane and Ragi – Tobacco are major sequential cropping system in South India (Anon (2014) and Wikipedia).

Similarly, some other finger millet based relay cropping systems in Southern Asian countries such as maize-millet (Pilbeam *et al.,* 2002; Sherchan *et al*., 1999), potato-millet (Saravanane *et al.,* 2011) and groundnut-millet (Kumara *et al*., 2014).

Mixed cropping

Growing two or more than two crops on same piece of land without definite row proportions is known as mixed cropping. Finger millet may be mixed with pearl millet, maize, sorghum, groundnut, tapioca, pulses and vegetables. Mixed cropping of finger millet with different pules or oilseeds reduce the weed and pest attack on the crop. According to AICRP report, another advantage of mixed/ intercropping that they suppress the pest and disease problem in the crop.

Strip cropping

Finger millet can be grown as strip cropping with different crops the main purpose of introduction of strip crop is to reduce soil erosion conservation of runoff water in sloppy regions. Some important finger millet based strip croppings are given below: Finger millet +Groundnut 6:9 proportion. In some parts of the countryragi can also grow as strip cropping with sugarcane and any other close-growing crops (Anon, 2014 and Wikipedia).

Approaches for sustainable production from finger millet based cropping systems

Optimum plant geometry

"The pattern of distribution of plants over the ground or the shape of the area available to the individual plant known as plant geometry."

To achieve more production from a particular crop based cropping system is depend on optimum plant population, raw proportion, spacing, type of crop, type of the variety of crop, duration of crop and variety are the

important factors which decide production from the cropping system. Pradhan *et al*., (2014) reported that intercropping of finger millet with pigeon pea recorded highest net returns and among the different row proportions FM+ Pegion pea 4: 1 recorded significantly higher growth parameters. There for many finger millet based cropping systems following in India which having different raw proportion according to growth habit of the component crops obtaining higher system yield than sole crop. Chandra *et al.*, (2013) reported that total yield, LER and system productivity index (SPI) were highest in the 75:100 seeding proportion of Finger millet: Black gram cropping system treatment and lowest in the sole crops. It is mainly due to the complementary relationship between finger millet and legume crop. Legume has unique characteristics like high protein content nitrogen fixing ability, soil ameliorative properties and ability to thrive better under unfavorable conditions.

Therefore Planting geometry, plant population plays important role in crop production if plant population below the optimum underutilization of resources and above the optimum overutilization of resources. Shashidhara *et al*., (2000) reported that ragi + pigeonpea (4:2) recorded significantly higher grain yield than ragi +pigeonpea (3:1) and ragi +pigeonpea (5:1) this might be due to the optimum plant population of finger millet in ragi + pigeonpea (4:1). Hence, to achieve maximum yield with optimum utilization of resources there should be optimum plant population of main crop or optimum row ratio of main and component crop in the cropping systems. Padhi *et al.*, (2010) and Poornima (2009) also reported similar result in finger millet based cropping systems. Maitra *et al*., (2000) and Mal *et al.*, (2010) also reported that plant density is the key factors of successful intercropping.

Intercropping

Growing of two or more crop on the same piece of land in same time with definite row pattern is known as intercropping. Intercropping provide a very much important role in sustainable production of finger millet because complementary interaction between finger millet and legumes intercropping which increase growth and yield of both the crop. It is mainly because of intercrop reduce weed density, reduce pest damage infestation due to the lack of host plants or by altering host plant availability and more efficient utilization of nutrient and water from the soil due to the different rooting depth and no or very less competition between the crop due to different growing habits these are the important role of intercrops which reduce the use of herbicide and other pesticides in crop production and promote to integrated use of all management practices in crop production which help in sustainable production of finger millet with efficient utilization of all available resources. Midega *et al.*, (2010) also reported that intercropping of finger millet effectively suppress the disease of the crop.

Weed management in FM based intercropping

Intercropping of finger millet with pulses and oilseeds significantly reduce weed population in the crop field because of more crop plant per unit area in intercropping systems which suppress the weed growth and also some crop plant act as trap crop or non-host crop which cause suicidal germination of parasite weeds and result death of the weed plant due to lack of host plant. Midega *et al.*, (2010) reported that intercropping of finger millet with Desmodium significantly reduce the striga population in the field it is mainly due to the desmodium act as a trap crop to the striga which stimulate germination of striga but due to the absence of host germinated striga plants

die this is known as suicidal germination. Chandra *et al.*, (2013) reported that the weed biomass was highest in sole finger millet plots (250 kg/ha) compare to intercropping.

Irrigation management

Generally, finger millet grown as rainfed situations which does not need any irrigation but during tillering and flowering stages, if rain delay for a long spell, then irrigation should be required to obtain a good yield. Furrows and ridges should be prepared for irrigation which would serve the dual purpose of irrigation and drainage. The crop does not do well under waterlogged conditions; therefore proper removal of excess water after rains is also essential. It is drought tolerance crop hence under drought or water scarcity condition supplemental irrigation at critical stages of the crop proving good yield from finger millet based cropping system.

Under drought prone area drip irrigation also alternative and effective method of irrigation to achieve good yield from finger millet based cropping system. Other management practices like the incorporation of crop residue, mulching, application of organic manure, intercultivation, growing of pulses in intercropping increase moisture conservation in the soil which leads more yield from finger millet based crop systems. Intercropping of finger millet with pulse also reduces soil erosion and nutrient loss from the top fertile soil. Jagadeesha (2009) reported higher water use efficiency under poultry manure compost and highest moisture retention under sewage sludge treatment. Which indicate that use of organic manure can increase water retention, effective rainfall which helps to produce more yield under water scarcity conditions.

Sequential cropping

Continuous growing of same crop on the same field cause deficiency of a particular nutrient in the soil due continuous removal of a specific nutrient from a specific depth of the soil, also cause dominance of a particular insect or disease or weed in crop because of continuous available favorable conditions and host plant which leads severe reduction in crop yield. Growing finger millet pulse or oilseeds sequential cropping are most effective in controlling insect, disease and weeds in the crop field and require less chemicals to their management and this type cropping system help to maintaining pests and weeds population below the economic threshold level/ damage threshold level which reduce dependence on herbicides and pesticides. Thereby these cropping system promote combine utilization of all natural and artificial resources of crop management which result more sustainable production from finger millet based cropping systems. Ananda (2006) reported more yield and yield parameters under application of NPK + FYM + $ZnSO_4$ + borax (T_9:5.13) as compared to other treatments. It is mainly due to balance supply of macro and micro nutrient to crop. Similarly Kumar Naik (2004) reported that among various treatment *Chromolaena's* compost, *Chromolaenaodorata* (90%) + cow dung slurry (10%) + microbial consortium + rock phosphate (2.5% of P) @ 7.5 t ha^{-1} + RDF (T3) gave relatively higher grain yield than other treatments. More yield and yield parameters are might be due to balance supply of nutrient and slow availability of nutrient to the crop throughout the growth period which leads the better growth of the crops toresult in more yield.

This indicates that rather an application of only chemical fertilizer or macronutrientwithout adding organic nutrient sources and micronutrient we cannot achieve full yield potential of the crop hence for sustainable more yield there should be balance supply of all nutrient through organic and inorganic sources of the nutrients.

Weed management in sequential cropping

Growing of the same crop on the field every year leads to the development of resistance in weeds against herbicide due to this minor weeds become a serious problem in field crops, also cause a deficiency of a particular nutrient in the soil due to continuous removal of nutrient from a specific depth. Growing of finger millet based intercropping or sequential cropping with different pulses and oilseeds is very much effective to control of parasite weeds of the main or component crop it is mainly due to lack of host plant. Growing of intercropping is very much effective to control weeds because of more plant population per unit area hence there is less space available to the weeds and result there is very less competition with the crop for nutrient, water, light and space which leads to reduce weed density and dry matter per unit area. Hence, intercropping or sequential crop are very effective to control weeds without the use of chemical herbicide. Similarly combine use of agronomic practice with physical chemical, mechanical and biological methods of weed control result in sustainable more yield for a longer period of time with efficient utilization of farm resources. Dhanapal *et al.,* (2015) reported that combined use of hand weeding can suppress weed population more effectively than single management practices. Combine use of all management practices can also maintain social, ecological, economical sustainability. Similar result reported by Sanjay *et al*., (2010).

Crop rotations

Crop rotation is very effective method to control of crop bound and season bound weeds in the crop field by changing host crops in the crop rotation. By following the principals of crop rotation in finger millet based cropping system like deep rooted followed by shallow rooted, more water requirement crop followed by drought tolerance, legumes crop followed by non-legumescrop these are the some most important principals of crop rotation which help to produce more sustainable yield with less cost of cultivation. Hence, crop rotation is an effective method for sustainable production of finger millet with efficient utilization crop input resources. Pavan Kumar (2014) reported that among the different combinations legume rotation system in finger millet recorded significantly higher yield compare to others similarly mono-cropped finger millet recorded significantly lesser straw yield (1900 kg ha^{-1}) than with the legume rotation (2900 kg ha^{-1}). Ramachandrappa *et al.,* (2016) reported that application of maize residue based integrated nutrient management treatments significantly influenced pH, EC, organic carbon, available P and available Kin the soil. Dam *et al.,* (2005) opined that the long-term application of corn residues may increase the levels of P and K in the soil.

Pests and diseases

Finger millet is known as hardiest crop but it is also affected by several pest and diseases among them major diseases such as blast, smut, foot rot, mottling and streak virus. Among the disease of fingermillet blast is the most serious disease which causes severe loss in yield of the crop because it affects different areal part of the plant and reduces growth, the number of panicle and grain formation in the panicle which result in very less yields per unit area. Hence, pest and disease management also very much important to produce more yield from the finger millet based cropping systems. Among the methods of pest and disease management integrated method by combined use of all management practices is very much effective for sustainable crop production from finger millet

based cropping system. Midega *et al.*, (2010) reported that intercroppingof finger millet with desmodium significantly reduce stem bore damage on finger millet It is mainly due to Desmodium act as a repellent to the stem borer which reduces insect damages in intercropping. This indicates that intercropping is an effective to the management of pest and disease in finger millet based cropping system. Bijender Kumar and Shukla (2012) reported that the significant effect of sowing dates in both the years of experimentation on blast incidence and grain yield was noticed and reported that the crop sown in mid plating window (17th June and 22nd June) recorded maximum incidences of neck and finger blast while the lowest incidences of neck and finger blast have been noticed in late planting window (27thJune and 3rd July).This indicates that by manipulating the date of sowing also can reduce disease and pest population and damage on the crop plants. Hence, finger millet should be sown at an optimum time according to their package of practice in different agro-climatic conditions reduce the risk of pest and disease in crops and reduce the cost of cultivation by the avoid use of chemicals for disease and pest management.

In conclusion, intercropping of FM/pulses can reduce the use of external inputs due to the complementary use of nutrient and water resources by the intercrop components. To grow the profitable intercropping systems in northern transitional zone of Karnataka in small milltes viz., ragi, little millet and foxtail millet with pigeonpea in 4:2 row proportion may be recommended. Intercropping of finger millet with *Desmodium intortum* significantly enhances grain yields and stover yield through effective control of both Striga and stemborers. Additionally, Desmodium has been found to conserve soil moisture, increase soil N and organic matter.

There is need to study on bio-fortification of zinc in finger millets, which is rich in minerals and fibers would be of a great role for sustainable cultivation and in human consumption. There is need to study precision nutrient, weed and water management in finger millet and finger millet based cropping system.There is need to develop crop models for predicting crop response to legume rotation and nutrient status of the soil needs to be analyzed. Studies on increasing micronutrient use efficiency with innovative technologies such as enriching with organic manures need to be carried out. Sustainability of legume-finger millet rotation needs to be evaluated for different agro-climatic zones of India.

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