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Weeds in finger millet and their management: A retrospect

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Abstract
Millets are a group of highly variable small-seeded grasses, widely grown around the world as cereal crops or grains for human food and as fodder. Fifty years back, millets were largely cultivated in Asia and Africa. Following the western model of development, fine cereals like rice, wheat and maize were popularised in place of millets due to change in food habits. Among major millets, finger millet is one of the most popular millets in India. Foods prepared from it, are recommended by physicians for patients and infants above six months age. Besides this, finger millet is a C4 crop which may yield more in future in the changing climatic scenario. Despite all the facts, both the growth and productivity of the crop are in declining trend due to several biotic and abiotic stresses. Among biotic stresses, weed infestation alone is responsible for yield loss up to an extent of 70% in finger millet. The crop grows slowly in the early stage of development. Weeds grow faster and have competitive advantages over crop during crop growth. Weeds deprive the crop from nutrients, water, light and space which ultimately reduces crop yield. So, the weeds need to be controlled right from the beginning and at least for 4-6 weeks of early crop growth. *Echinochloa colona*, *Digitaria sangunalis*, *Cyanadon dactylon*, *Panicum milliacea*, *Dactyloctenium aegyptium*, *Cyperus rotundus*, *Amaranthus viridis*, *Eleusine indica*, *Celosia argentia*, *Commelina benghalensis*, *Euphorbia geniculate* etc. are the major weed species found in finger crop. Farmers have less knowledge about proper weed management practices in finger millet. They should be trained regarding different aspects of weed management *viz*. preventive methods, mechanical methods, cultural methods, chemical methods and their integration as a holistic approach of weed management in finger millet. Several methods of weed management in finger millet have been standardised by different workers. The available options are discussed in this paper.

Keywords: finger millet, weed diversity, crop-weed competition and weed management

Introduction

In an anticipation, FAO (2005) [8] stated that climate change may severely impact food production and food security in many draught-prone regions worldwide, which may lead to shrinkage of dietary range and reduction of total food consumption resulting malnutrition problems and food insecurity (IPCC 2007) [12]. A key question is there in front of us that whether we will be able to feed the projected global population of 9 billion in 2050 justifiably, healthily and sustainably (Beddington 2010) [3]. Most of the world population depends upon cereals like rice, wheat and maize whereas the millets have been being regarded as neglected crops (Shukla *et al.* 2015) [27]. A dozen of millets originated in third world countries which were domesticated and cultivated by different tribes and resource poor farmers of tropics and semi-arid regions of Asia and Africa (Saleh *et al*. 2013) [24]. Mostly millets are well-known for their capacity to withstand adverse condition. These are characterised by their extraordinary capacity to survive in less fertile soil, to resist drought, insect pests and diseases, short growing season (70-80 days), well fitted in to multiple cropping systems both under irrigated and rainfed conditions, and amazing nutritional content (three to five times nutritionally superior than rice and wheat in terms of protein, minerals and vitamins) (Devi *et al*. 2014 [6]; Subramanian *et al*. 2010 [29]; Trivedi *et al*. 2015) [31]. Being the most important component of the nutritional security programme, millets are called as "Nutri Cereals".

Among different major millets, finger millet (*Eleusine coracana*) (locally called by various names including *ragi*, *kezhvaragu*, *ragulu*, *nachani*, *mandua*, *mandia*) is an important crop of India which is mostly grown and consumed in Karnataka, Andhra Pradesh, Tamil Nadu, Odisha, Maharashtra, Garhwal and Kumaon (Uttarakhand), Rajasthan, Dang District (Gujarat) and Goa. Karnataka produces about 53% of total finger millet production in the country, followed by Tamil Nadu (15%), Uttarakhand (10%) and Andhra Pradesh (7.5%) during 2013-14. It is a rich source of Ca (3000-3500 ppm), P (2830 ppm) and Fe (39 ppm) (Gopalan *et al*., 2000), vitamin B1, B2, folic acid and niacin (Vidyavati *et al.* 2004) [32]. 100 g of finger millet provides 328 kcal of energy (Banerjee and Maitra 2020) [4]. In addition to its growth ability in adverse condition and very good nutritional content, it is very useful in diet for infants as well as patients. Being a C4 crop, there is a ray of hope that finger millet will play important role under changing climate (Gupta *et al*. 2017) [10]. It is observed that the production and productivity of finger millet are declining in the post green revolution era due to various reasons. The crop growth is slow during the initial phase of its life cycle. Out of major biotic stresses, weed infestation is the one of the biggest problems during this period. This

article thrusts on different aspects which will help in better understanding of weed menace and its management in finger millet.

Weed flora composition

Factors like type of crop, season, method of cultivation, climate, edaphic and biotic factors greatly influence the weed diversity and distribution. Weed flora has a very wide diversity within them; types of weeds species, its density and dry weight directly influence the extent of yield loss in different crops. As the competing ability of these diverse weed floras are different; it is essential to have the knowledge about biology and ecology of weeds in order to manage them effectively. Reddy *et al*. (1990) [23] observed major weed flora like *Cyperus rotundus* (among sedge), *Digitaria marginata*, *Eragrostis pilosa*, *Dactyloctenium aegyptium* (among grasses), *Acanthospermum hispidum*, *Cleome monphylla*, *Polygonum plebejum* in drilled sown finger millet. Besides these weeds, finger millet was also found to be associated with *Echinocloa colona*, *Echinochloa riparia*, *Phyllanthus fraternus*, *Oldenlandia corymbosa*, *Commelina bengalensis*, *Spillanthus acmella* and *Emilia sanchyfolia* (Ramachandra *et al*. 1991) [21]. Under irrigated finger millet, major weeds like *Cyperus rotundus* (L.), *Echinochloa colona* (L.), *Cynodon dactylon* (L.) Pers, *Dactyloctenium aegyptium* (L.) Beauv., *Digitaria marginata* (Retz.), *Eragrostis pilosa*, *Eleusine indica* (L.) Gaertn, *Parthenium hysterophorus*, *Alternanthera sessilis*, *Sida acuta*, *Spillanthus acmella*, *Commelina benghalensis*, *Ageratum conyzoides*, *Ocimum canum*, *Cinebra didema* etc. were observed (Patil *et al*. 2013) [18]. *Echinochloa colona*, *Digitaria sangunalis*, *Cyanadon dactylon*, *Panicum milliacea*, *Cyperus rotundus*, *Dicanthium caricsum*, *Commelina bengalensis*, *Stachytarpeta indica*, *Borrerhia hispida*, *Trichodesma indica*, *Emelia sanchyfolia*, *Cardiospermum helicabum*, *Polygonum plebejum*, *Amaranthus viridis*, *Eleusine indica*, *Celosia argentia*, *Commelina benghalensis*, *Euphorbia geniculata* were other major weeds associated with finger millet under rainfed situations (Kumara *et al*. 2007 [14]; Pradhan and Singh, 2009 [19]). In an experiment in Uganda, Nyende *et al*. (2001) [17] reported that *Digitaria scalarum* was the most serious weed in finger millet which was very difficult to control. In order to harness the maximum yield benefit in finger millet, the weeds need to be kept under control by adoption of suitable weed management strategies.

Crop-weed competition and losses due to weed infestation

Crop-weed competition starts when the availability of growth resources falls below their combined demand. The competition between crops and weeds can be above ground (solar radiation and CO_2), underground (nutrient, moisture and oxygen), and both (space). Millets are slow growing in nature in the first few weeks of their growth. Hence, weeds grow faster and smother the crop causing decline in crop yield. The losses due to weed infestation in millets are (i) direct yield loss from reduced crop quality, (ii) indirect yield loss from reduced crop quality, (iii) increased cost of harvesting, cultivation and agronomic operations, and (iv) the ability of weeds to harbour insect pests and disease pathogens (Mishra *et al*. 2018) [16].

The critical crop-weed competition period in finger millet ranges from 25-42 days after sowing (Sundraesh *et al*. 1975) [30]. Reduction in grain yield varies from 5-73% in finger millet (Table 1).

Table 1: Yield loss due to weed infestation in finger millet

Reduction in grain yield (%)	References
55-61	Ramachandra *et al*. (1991) [21]
5-70	Rao *et al*. (2015) [22]
73	Asargew and Shibabawu (2014) [1]

Weed Management Methods

Weed control is a never-ending process in agriculture. They can't be completely eradicated but should be managed and kept under certain threshold limit in order to get maximum economic return from the crop. The initial 4-6 weeks of the crop is important from the weed management point of view. Once the crop attains about 0.5 m height, it keeps pace and suppress the weed growth. There are several strategies *viz*. preventive methods, mechanical methods, cultural methods and chemical methods. The strategies are explained below.

1. Preventive methods

Nature has equipped the weeds with immense potential to be well disseminated through various means and thrive well in various unfavourable environmental conditions. It is better to control weed species during early stage of crop growth. Keeping in view economic and practical feasibility, the probable means of weed seed dispersal and distribution throughout the field should be avoided to check the menace caused by the weeds in millets. The following strategies should be adopted in field for better finger millet crop.

a. Use of weed-seed free seeds
b. Use of clean agricultural implements
c. Use of weed-seed free irrigation water
d. Irrigation channel should be free from weed plants
e. Use of well decomposed compost or farm yard manure
f. Regular destruction of seeds, tubers and rhizomes of already present weed species in the farm
g. Quarantine measures should be taken when seeds are imported

2. Mechanical methods

Mechanical method is the physical method of weed control which is often adopted in millets by the farmers. Weeds have been naturally equipped with characteristics like prolific seed production and vegetative propagation through swollen roots, rhizomes, bulbs etc. which remain dormant inside the soil for many years and give rise to plants when favourable environment arises. In this method, both above ground weed plants as well as the below ground propagules are removed. It includes manual hand weeding, deep summer tillage, fallow-season tillage, pre-plant tillage and post-plant shallow tillage/inter-cultivation. Millets are mainly grown in semi-arid areas where inter-cultivation helps in conservation of soil moisture. Vijaymahantesh *et al*. (2013) [33] reported satisfactory weed control in conventional tillage by inducing germination of weed seeds. Germinated weeds were killed by repetitive cultivation which caused less weed population and higher yield of finger millet crop. Sidar and Thakur (2017) [28] found that summer tillage recorded lower weed population and dry matter leading to higher grain and stover yield, and harvest index. Erratic rainfall during rainy season brings difficulty in timely hand weeding by farmers. Moreover, labour scarcity also causes major problems at peak time of weeding.

3. Cultural methods

Cultural methods of weed control are environment friendly which can be adopted through different practices like tillage, plant population management through seed rate, spacing, intercropping, crop rotation, mulching, management of time and method of sowing, irrigation and nutrient application etc.

Growing of leguminous crops like green gram, cowpea, soybean, groundnut etc. as intercrop helps in better smothering the inter-row space through their quick growing ability which restricts solar radiation utilisation by germinated weeds. Similarly increasing plant population by higher seed rate and narrow spacing also enables the millet crops to get better competitive ability. Sidar and Thakur (2017) [28] reported that practices like opening of conservation furrow and intercropping of red gram with finger millet increased the yield of finger millet by reducing the weed population and dry weight. In Uganda, Nyende *et al*. (2001) [17] observed that row seeding of finger millet crops with a spacing of 30 cm × 6 cm and one weeding proved better than broadcasting with two hand weedings in terms of yield and economics with reduction in weed population up to 50%.

4. Chemical methods

Chemical method of weed management is the most popular method among farmers due its cost and time effectiveness as well as efficiency in reducing the weed population. Herbicides are considered to be best tool in suppressing weeds of any crop as it controls the weeds right from the beginning of the crop cycle which gives competitive advantage to the crops. The herbicides are classified in to three categories according to their time of application *viz*, pre-planting herbicides (applied before planting of crops; e.g., fluchloralin), pre-emergence herbicides (applied after planting of crop but before emergence of weeds; e.g., atrazine, pretilachlor, metolachlor and pendimethalin), and post-emergence herbicides (applied after emergence of weeds; e.g., 2, 4-D and bispyribac-sodium). Herbicides have become an integral part in conservation agriculture (Brown *et al*. 2004) [5]. Herbicides alone often provide a narrow window of weed control. Hence, several combinations of herbicides *viz*. herbicide mixtures and sequential application of herbicides are standardised to obtain a broad-spectrum weed control over weeds in finger millet. Some of the recommended herbicide combinations have been given in Table 2.

Table 2: Recommended herbicides, herbicide mixtures and sequential application herbicides for weed control in finger millet

Herbicides	Dose (kg ha^{-1})	Time of application	Weeds controlled	Reference
Oxadiargyl *fb*	0.08	3 DAS	Effective against a wide range of weeds (Broad spectrum)	Shubhashree, and Sowmyalatha (2019) [26]
Ethoxysulfuron	0.012	30 DAS		
Butachlor	0.75	Pre-emergence	Effectively controls the grasses	Dhanapal *et al*. (2015) [7]
Isoproturon *fb*	0.5	Pre-emergence	Effective against a wide range of weeds (Broad spectrum)	Kujur (2016) [13]
2,4-D Na salt	0.5	Post-emergence		
Bensulfuron-methyl + pretilachlor	0.06 + 0.60	Pre-emergence (2 DAT)	Effective against a wide range of weeds (Broad spectrum)	Banu *et al*. (2016) [2]

***DAS:** days after sowing; DAT: days after transplanting

Integrated weed management methods

Integrated weed management is the holistic approach of weed control which is environment friendly, more efficient and sustainable than any other single approach of weed management. It comprises different combinations of weed controls as per requirement of the situation. Chemical method is though effective and efficient but prolonged use of herbicide leads to several problems like environment contamination, herbicide resistance, weed flora shift etc. Some of the standardised integrated weed management practices in finger millet have been given in Table 3.

Table 3: Integrated weed management in finger millet

Integrated weed management strategies	Reference
Metoxuron at 0.75 kg ha^{-1} (PE) *fb* 1 HW at 30 DAS	Manjunath and Muniyappa (1990) [15]
Isoproturon at 0.5 kg ha^{-1} (PE) *fb* 2 hand inter-cultivation at 20 and 40 DAS	Pradhan and Singh (2009) [19]
Oxyflurofen at 0.50 kg ha^{-1} *fb* 2 HW at 20 and 45 DAS	Pradhan *et al*. (2010) [20]
Bensulfuron methyl + Pretilachlor at 3 kg ha^{-1} (pre-mix formulation) *fb* one inter-culture at 45 DAS	Satish *et al*. (2018) [25]
Oxadiargyl 80 WP at 0.15 or 0.20 kg ha^{-1} (within 3 DAS) *fb* one inter-cultivation at 25-30 DAS	ICAR-AICRP on Small Millets (2019-20) [11]
Bensulfuron ethyl 0.6 + Pretilachlor 6.0 G at 0.33 kg ha^{-1} (within 3 DAS) *fb* one inter-cultivation at 25-30 DAS	ICAR-AICRP on Small Millets (2019-20) [11]
Bispyribac sodium 10 SC 0.01 or 0.015 kg ha^{-1} (within 15-20 DAS) *fb* one inter-cultivation at 35-40 DAS	ICAR-AICRP on Small Millets (2019-20) [11]

***DAS:** Days after sowing

Conclusion

Finger millet is going to be the future crop keeping an eye on the prevailing changing climatic scenario. In future, finger millet is going to have high demand in market. We need to emphasise on increasing the productivity of the crop. Weeds compromise a greater portion of yield in finger millet like other crops. Weeds are difficult to be identified in the early stage of crop growth and in that period, weeds cause drastic loss of external inputs like water and fertiliser depriving the crop from that. Low energy manual or mechanical weeders should be developed. In order to reduce crop loss due to weed infestation in millets, timely and proper weed management strategies *viz*. preventive methods, mechanical methods, cultural methods and chemical methods should be adopted in an integrated manner according to the prevailing situation of weed diversity, climatic condition and crop ecology. Herbicides are the best tools in weed management with respect economy, time, energy and efficacy. But use of herbicides with same mode of action in a long run needs to be replaced by application of herbicide mixtures and sequential application of herbicides. Farmers are often not aware of

type of herbicide, dose, time and proper application method. They need to be trained. More efficient integrated weed management strategies need to be standardised.

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