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Weed Management in Millets

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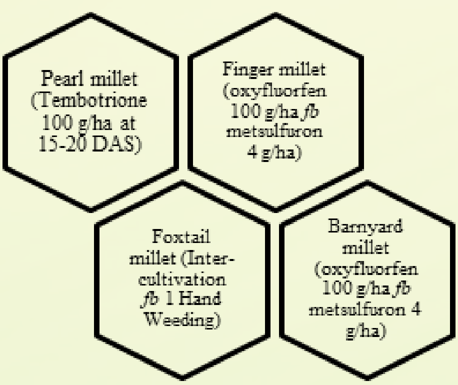

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Foreword

The year 2023 has been declared as the ‘International Year of Millets’ by the United Nations. India is the global leader in production of millets (Shree Anna) with a share of around 15% of the world’s total production. Millets are rich source of nutrients and minerals, and are being promoted as ‘nutri-cereals’. Being C_4 crops, they are physiologically more efficient, hardy in nature, drought tolerant and thus climate resilient.

A variety of millets viz. sorghum, pearl millet, finger millet, barnyard millet, proso millet, kodo millet, little (Kutki) millet and foxtail millet are traditionally grown in resource poor agro-climatic regions of the country. However, heavy infestation of complex weed flora especially during rainy season causes 15-83% reduction in yield. The management of grassy weeds in millets is very difficult due to crop mimicry and non-availability of selective herbicides. Because of the slow initial growth, early 30 days period are more critical for weed competition. Hence, timely weed management in millets is of utmost importance for obtaining higher yields. In general manual and mechanical weeding is the most common method of weed management in millets. Few selective herbicides have been recommended in sorghum and pearl millet.

The ICAR-Directorate of Weed Research (DWR), Jabalpur is making sincere efforts to develop integrated weed management technologies to reduce crop losses due to weeds and increase the productivity and production of millets in the country and the present publication entitled “Weed Management in Millets” is based on the research work done under AICRP on Weed Management in different agro-climatic regions and at the DWR on weed management in millets. I compliment the scientists for generating valuable information on weed management in millet cultivation. I hope the present bulletin shall be of immense value and source of information to the researchers, students and other stakeholders.

(Dr. S. K. Chaudhari)

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Preface

Millets are a group of small seeded cereals grown for food and fodder. They are sorghum, pearl millet, finger millet, kodo millet, foxtail millet, barnyard millet, little millet, proso millet and browntop millet. Buckwheat, quinoa and amaranth although not cereals are categorized as pseudo-millets. These millets are rich source of nutrients, minerals, vitamins, antioxidants and higher dietary fibre and therefore promoted as nutri-cereals. They are gluten-free and have low glycemic index than rice, wheat and maize. Many life-style diseases i.e., diabetes, high blood pressure, osteoporosis etc. can be managed by regular intake of millets. However, in present scenario, demand for millets for direct consumption has declined due to change in food habits and inconvenience attached with food preparation as compared to fine cereals like rice and wheat. Millets being C_4 crops are more efficient physiologically, hardy in nature, drought tolerant and thus climate resilient. In view of the importance of millets, the Government of India took initiative to bring back the cultivation and consumption of millets to a higher level in the country and introduced several schemes on food and nutritional security to promote their cultivation and consumption.

Millets are generally cultivated on rainfed, marginal and impoverished lands which makes them more susceptible to weed infestation and loss in yield and quality. Being rainy season crops, these are infested with 'difficult- to- control' grassy weeds (*Sorghum halepens, Eleusine indica, Echinochloa colona/crus-galli, Panicum repens, Paspalidium flavidum, Setaria glauca*, etc.) as well as many broad-leaved weeds and sedges, reducing the crop yields by 15-83%. The management of these grassy weeds in millets is very difficult due to crop mimicry and non-availability of selective herbicides. The ICAR-DWR and coordinating centres of AICRP-WM took initiative and conducted studies on weed management in some of the millet crops which have been compiled and presented in this technical bulletin. It is hoped that the information presented in this publication will be of use to researchers, students and farmers.

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Contents

Introduction

Millets are considered to be the earliest domesticated food crops in Asia and Africa. These crops have been categorized in two groups, major millets i.e., sorghum (*Sorghum bicolor* L.), pearl millet (*Pennisetum glaucum* L.) and minor or small millets comprising finger millet (*Eleusine coracana* L. Gaertn.), barnyard millet (*Echinochloa frumentacea* L.), little millet (*Panicum sumatrense* Roth ex. Roem. and Schult.), foxtail millet (*Setaria italica* L.), kodo millet (*Paslpalum scrobiculatum* L.), proso millet (*Panicum miliaceum* L.) and brown-top millet (*Panicum ramose* L.). Two pseudo-cereals i.e., buckwheat (*Fagopyrum esculentum* L.) and amaranth (*Amaranthus viridis* L.) have been included under nutri-cereals.

Millets in India were traditionally consumed, and grown as mixed and intercropping on marginal lands with low or no inputs resulting in low yield. However, with the development and release of hybrids and improved varieties especially in sorghum, pearl millet and finger millet, with improved production technologies, the productivity of these major millets has improved a lot, resulting increase in total production in spite of significant reduction in area in the last 4-5 decades Although, some of the small/minor millets like barnyard millet and proso millet have high yield potential, the productivity is still quite low, which needs to be increased through development and adoption of better genotypes and improved management practices. The millets are being promoted as nutri-cereals and as future crops. The Government of India realized the importance of millets in building nutritional security in the country and made several efforts such as gazetting millets as Nutri-Cereals, the celebration of the National Year of Millets in 2018, and several small-scale policies on millets to promote millet cultivation and utilization through creating awareness, production, processing and value addition. On the initiatives of Govt. of India, the United Nation has declared the year 2023 as "International Year of Millets" to promote its cultivation and consumption.

Area, production and yield of millets (2020-21) in India

Crop	Area (mha)	Production (mt)	Yield (kg/ha)
Pearl millet	7.65	10.86	1420
Sorghum	4.38	4.81	1099
Finger millet	1.16	1.99	1724
Minor millets	0.44	0.35	781
Total	**13.63**	**18.01**	

(Source: (https://apeda.gov.in/apedawebsite/index.html)

Weeds are one of the major obstacles in increasing the productivity of millets especially during rainy season. Millets are relatively poor competitor for weeds during the early growth stages (first few weeks) of the crop. During this phase, crops grow slowly compared to the weed species and this creates better conditions for weed growth. It takes up to the mid-season for the millets to develop good canopy that can cover and shade the space between the rows and discourage weed growth. Planting in wider rows to facilitate inter-row cultivation worsens the problems. Appropriate weed management would help improve productivity and input use-efficiency of these crops. When improved agricultural technologies are adopted, efficient weed management becomes even more important, otherwise the weeds rather than the crops benefit from the costly inputs.

Crop-weed competition and yield losses

Weeds compete with crop for nutrients, soil moisture, space and sunlight. Millets are poor weed competitors in the early stage of growth. It is important to control weeds during the critical period of weed competition which is around 25-40 days after sowing/planting. If not controlled timely these harmful plants reduce the yield of sorghum (15-83%), pearl millet (16-94%), finger millet 55-61 and kodo millet by 46%. In addition, weed infestation causes increased cost of cultivation, reduction in quality of the produce, and acts as host for pests and pathogens. As most of the millet-lands sufferer from poor soil fertility due to their marginal nature, the removal of nutrient by the weed further deteriorates the situation. Similarly, depletion of soil moisture by weeds, may create a severe moisture deficit conditions for the millets to grow.

Major weeds infesting millets

Millets are mostly grown in the *Kharif* season, hence most of the rainy season weeds of the particular agro-ecological zone infest millet crops. Major among grasses are *Echinochloa colona, E. crus-galli, Cynodon dactylon, Dactyloctenium aegyptium, Brachiaria ramosa, Digitaria sanguinalis, Eleusine indica, Panicum reptans, Dinebra retroflexa, Paspalidium flavidum* etc., the major broad-leaved are *Euphorbia geniculata, E. hirta, Alternanthera sessilis, Physalis minima, Digera arvensis, Commelina benghalensis, C. communis, Amaranthus viridis, Trianthema portulacastrum, Ageratum conyzoides, Celosia argentea, Eclipta alba, Mollugo pentapyhla, Phyllanthus niruri, Leucas aspera, Striga asiatica* etc., among sedges *Cyperus rotundus, C. iria, C. esculentus* are the major ones.

Weed management options

Millets are primarily grown on under-nourished soils with poor crop management. Improper agronomic practices like broadcasting method of seed sowing and fertilizer application help in abundant growth of weeds. Weeds in these crops are mostly managed by weeding once at the early growth stage. Herbicide use is restricted due to non-availability of selective herbicides in millets. Different weed management options in millets could be:

i. Preventive methods

ii. Stale seed-bed

iii. Reduced crop row spacing

iv. Mulching

v. Intercropping with legume crops

vi. Inter-culture/weeding

vii. Herbicide-use

Very few herbicide recommendations for weed management in millets are available at present. In pearl millet and sorghum herbicides like atrazine (500 g/ha), pendimethalin (650 g/ha), metolachlor (700 g/ha) and 2, 4-D (500 g/ha), in barnyard millet, bensulfuron methyl + pretilachlor (550 g/ha), in transplanted finger millet and barnyard millet, atrazine (700 g/ha), metribuzin (150 g/ha), oxyfluorfen (100 g/ha), pyrazosulfuron (20 g/ha) and 2, 4-D (500 g/ha), and metribuzin (150 g/ha), oxyfluorfen (100 g/ha), pendimethalin (600 g/ha), isoproturon (500 g/ha) and metsulfuron (4 g/ha) may be used in kodo millet.

Sorghum

Sorghum (*Sorghum bicolor* L. Moench) is the third most important food grain crop after rice and wheat. It is a principal source of protein, vitamins, energy, and minerals for millions of people, especially in the semi-arid regions. Weeds are a major constraint in obtaining higher production. AICRP weed management trials spread across 3 sorghum-growing states; Karnataka, Maharashtra and Madhya Pradesh indicated 25.1% weed-associated yield losses (Gharde *et al*., 2018).

Himachal Pradesh (CSKHPKV, Palampur)

Weed flora: In una district during 2008-09, sorghum cultivation was observed along the route (Chintpurni- Jourbarh-Prithipur-Dangoh-Deoli-Oeal). Six weed species invaded this crop. Among these *Ageratum conyzoides* had the highest IVI value of 86.23 followed by *Cassia tora* (60.13) and *Xanthium strumarium* with IVI value of 51.45 (Table 1).

Table 1. Distribution of different weed species in Sorghum in Una district.

Name of species	Freq.	RF	D	RD	Dom	RD	IVI	SDR
Chintpurni- Jourbarh-Prithipur-Dangoh-Deoli-Oel (Route-I)								
Ageratum conyzoides	100	16.67	32	34.78	32	34.78	86.23	43.12
Digitaria sanguinalis	100	16.67	8	8.69	8	8.69	34.05	17.03
Eleusine indica	100	16.67	8	8.69	8	8.69	34.05	17.03
Xanthium strumarium	100	16.67	16	17.39	16	17.39	51.45	25.73
Parthenium hysterophorus	100	16.67	8	8.69	8	8.69	34.05	17.03
Cassia tora	100	16.67	20	21.73	20	21.73	60.13	30.07

D=Density; RF=Relative Frequency; RD=Relative Density; IVI=Importance Value Index; SDR=Sum Dominance Ratio

Weed management in fodder sorghum + pearl millet combination

Single-cut sorghum and multi-cut pearl millet varieties are cultivated for green fodder (forage). Pearl millet uses less water per unit of forage production, tolerates both lower and higher soil pH and higher aluminium, and is rich in minerals as compared to sorghum. However, sorghum has wider adaptability and is widely grown. Forage quality is paramount to palatability or acceptability and animal intake. The weeds have major threat to production and quality of forage. Thus, there control is indispensable in the fodder sorghum + pearl millet crop combination. Keeping in consideration, weed control technology was demonstrated in Kangra district of Himachal Pradesh.

The major weeds found growing in association with the crop were *Ageratum conyzoides*, *A. houstonianum*, *Polygonum alatum*, *Persicaria hydropiper*, *Echinochloa colona*, *Panicum dichotomiflorum* and *Setaria glauca*. Pendimethalin 0.75 -1.0 + atrazine 0.5-0.75 kg/ha increased fodder yield of sorghum + pearl millet combination by 28.3% (Table 2).

Table 2. Demonstrations on sorghum + pearlmillet crop combination during *Kharif* 2020.

Crop	No of farmers	Average yield (t/ha)		% increase
		Demonstration	Check	
Fodder sorghum/pearl milet	4	45	35	28.3

Note: In fodder pendimethalin + atrazine (variable across villages) v/s farmer's practice were evaluated in Kangra district of Himachal Pradesh.

Rajasthan (MPUAT, Udaipur)

Weed management in *Kharif* grain sorghum

Weed flora: Awnless barn-yard grass [*Echinochloa colona* (L.) Link], tropical spider-wort (*Commelina benghalensis* L.), green foxtail grass [*Setaria glauca* (L.) Samp.], and viper grass [*Dinebra retroflexa* (Vahl) Panz.] are among the monocot weeds, while false amaranth [*Digera muricata* (L.)Mart.], giant pigweed (*Trianthema portulacastrum* L. and sunnberry (*Physalis lagascae* Roem. & Schult.; syn. *minima* L.) are the dicot weed flora in the sorghum crop.

Weed density, weed dry weight and weed control efficiency

Monocots were dominant, as evident from 78.2 (80.7%) of their share in total (monocot + dicot) density (weight) during 2020 (mean of 20, 40 DAS and harvesting). Atrazine (PE) application has effectively managed diverse sorghum weed flora. This is evident from the fact that there was 47.3 and47.6% lower weed density and weed weight values (4.53 and 3.11 g/m^2) in atrazine (PE) treatments than the weedy check (8.60 and 5.93g/m^2). However, atrazine (PE) treatments resulted in markedly higher weed density and weed weight values than the weed free treatment (2.34 and 1.66 g/m^2). At 30 DAS, atrazine (PoE) application caused 16.4% (7.8%) reduction in weed density (weed dry weight) compared to atrazine (PE). Due to the emergence of new weeds, the impact of atrazine (PoE) on weed density dropped to 7.44% by 40 DAS, whereas weed weights remained constant at 7.43% (PE). Pooled data at harvesting stage also showed superiority of atrazine (PoE) application with 7.79% (7.97%).

Grain and stover yield

In rainy season grain sorghum, uncontrolled weeds reduced the grain and stover yields by 64 and 55%, respectively, as compared to weed-free treatment (3.47 and 12.34 t/ha) (Table 3). Atrazine (PE) application has bridged the above grain and stover yield gap between weedy check and weed-free treatment by 80.4 and 89.0%. Atrazine (PoE) over its PE failed to boost the productivity and, on the contrary, lowered the grain and stover yields by 3.95 and 7.25% on account of slight phytotoxicity (0.67). Both the HPPD enzyme inhibitive PoE herbicides, i.e. tembotrione (0.0189 kg/ha) and topramezone (0.0242 0.0363 kg/ha) proved ineffective as evident from their at par grain yields as weedy check (1.26 t/ha). However, stover yields recorded with tembotrione and topramezone at their higher dose (0.0363 and 0.189 kg/ha) were markedly lower (15.1 and 19.6% lesser) to weedy check (5.49 t/ha). The reduction in stover yields could be attributed to the plants' in-ability to generate panicles rather than the shorter plant heights. In comparison to atrazine PE (3.04 t/ha), both topramezone and tembotrione as PoE following atrazine (PE) reduced the sorghum grain yields by 39.1 and 62.2% at low dose and 52.3 and 59.9% at high dose respectively. Reductions in stover yields were almost of similar magnitude as that of grain yield. On account of taller plants and higher yield attributes, weed-free treatment recorded the highest grain and stover yields while the least by the weedy check. Grain yields in the other herbicidal treatments were moderated as a product of yield attributes when compared to weed-free and weedy check treatments.

Weed index and Herbicide efficiency index

Weed index (WI), a measure of yield reduction from weed-free treatment, were the least (11.71) and the highest (66.20) with atrazine (PE) + topramezone (0.0189 kg/ha, PoE) and the latter's WI was at par with that of weedy check (63.57). On the contrary, HEI, a measure of yields over weedy check, were highest in weed-free treatment (4.74) and decreased with the use of PoE herbicides. Topramezone (0.0189 kg/ha) showed the least (–0.26) HEI value. The high WI and low (even negative) HEI values with topramezone and tembotrione herbicides compared to atrazine (PE) proves the phytotoxicity effects to grain sorghum crop.

Economics

Weed-free (hand-weeding at 15 and 35 DAS) treatment costing ₹8,000 enhanced the cost of grain sorghum crop production by 31.3% over weedy check (₹25,565) and revealed the markedly higher net income than all the other weed-management treatments (₹135,126) (Table 3). Atrazine (PE), though costed only 11.4% of weed-free treatment. However, on account of its 12.4 and 6.2% lower grain and stover yields significantly lowered the net returns (6.7%) com-pared with weed-free treatment. Higher BC ratio of atrazine (PE) was ascribed to its 21.1% lower cost of production than weed-free treatment. Topramezone (0.0189 kg /ha) and tembotrione (0.0363 kg/ha) as PoE compared to atrazine (PE) resulted in 35.4 and 28.6% lower net returns than weed free treatment (₹41,875). Over atrazine (PE), topramezone (0.0126 and 0.0189 kg/ha) and tembotrione (0.024 and 0.0363 kg/ha) have resulted in 51.4 and 21.4 and 41.0 and 23.7% loss in net revenues. Net income and BC ratio of 2019 were 43.1 and 29.6% higher than 2020 (₹61,009 and 3.08) on account of 10.8 and 51.7% higher grain and stover yields.

Table 3. Yield and economics of rainy season grain sorghum cultivation under different weed-management practices (pooled data).

Treatment	Weed control efficiency (%)	Grain yield (t/ha)	Stover yield (t/ha)	Net returns (₹/ha)	BC ratio
Atrazine 0.50 kg/ha (PE); T1	76.57	3.04	11.58	126060	5.76
T1 + atrazine as PoE at 20 DAS	79.98	2.92	10.74	116772	5.26
T1 + topramezone 0.0126 kg/ ha (PoE, 25 DAS)	90.98	1.85	7.50	64738	3.12
T1 + tembotrione 0.0242 kg / ha (PoE, 25 DAS)	92.56	1.45	7.17	51673	2.67
T1 + topramezone 0.0189 kg/ ha (PoE, 25 DAS)	95.33	1.15	4.42	27034	1.87
7T1 + tembotrione 0.0363 kg/ ha (PoE, 25 DAS)	95.13	1.22	4.66	29903	1.94
Weed-free -(hand-weeding at 15 and 35 DAS)	95.68	3.47	12.34	135126	5.03
Weedy check	2.08	1.26	5.49	41875	2.64
CD (P=0.05)	-	0.224	0.783	6882	0.224

DAS, Days after sowing; PE, pre-emergence; PoE, post-emergence

It is concluded from the study that pre-emergence atrazine 0.5 kg/ha was the best herbicide weed-management option for rainy season grain sorghum of Rajasthan though weed-free situation created through 2hand-weedings at 15 and 35 days after sowing proved the best. The HPPD (p-hydroxy-phenyl-pyruvate dioxygenase) enzyme-inhibitive post-emergence herbicides (topramezone and tembotrione) though highly effective for weed management but on account of their phytotoxicity proved to be of no practical utility at the doses tested.

Weedy check

Atrazine 0.50 + Tembotrione 0.0363 kg/ha

Rajasthan (SKNAU, Jobner)

Management of *Sorghum halepense* (Johnson grass, Baru) in Sorghum

Sorghum halpense (Baru) has become most problematic weed in sorghum crop in the IIIA zone of Rajasthan. The study was formulated to manage most problematic specific weed, *Sorghum halpense* (Baru) in sorghum crop. The research trial was conducted under the RKVY sponsored project at the identified hot spots on the farmer's field in the zone IIIA of Rajasthan.

Application of tembotrione 100 g/ha as post-emergence (15-20 DAS) significantly controlled *Sorghum halepense* over other treatments at 30 DAS during *Kharif* 2018, 2019 and 2020. Highest grain yield and strover yield were observed in weed free, which was found at par with tembotrione 100 g/ha during all the years (Table 4).

Table 4. Effect of herbicides on management of *Sorghum halepense* (Johnson grass), yield and economics of sorghum (*Kharif,* 2018-20).

Treatments	Density (*Sorghum halepense*) at 30 DAS (No./m^2)				WCE at 30 DAS (Mean)	WI (Mean)	Grain Yield (q/ha)	Stover Yield (q/ha)	BC ratio
	2018	2019	2020	Mean					
Weedy check	18.7	26.7	28.1	24.5	0	38.68	11.38	26.59	0.73
Quizalofop ethyl 70 g/ha as PoE	17.2	21.0	23.6	20.6	16.04	22.94	14.30	33.83	1.17
Tembotrione 100 g/ha as PoE	7.9	6.0	7.1	7.0	71.39	4.67	17.68	39.54	1.44
Fluazifop-p-butyl 200 g/ha as PoE	17.6	21.5	20.7	19.9	18.66	16.65	15.46	36.12	0.99
Weed free	0.0	0.0	0.0	0.0	100.00	0.00	18.82	41.58	1.28
CD (P=0.05)	1.0	1.7	2.1						

Weedy check

Tembotrione 100 g/ha as PoE

Uttarakhand (GBPUAT, Pantnagar)

Several herbicides either alone or in combination have been recommended for weed management in sorghum crop in Uttarakhand (Table 5).

Table 5. Herbicides recommended for weed control in sorghum

Herbicide	Dose (kg/ha)	Time of application	Weeds controlled	Remarks
Atrazine	0.75-1 .0	Pre-emergence/ early post-emergence	Broad-spectrum weed control. Some grasses are tolerant	For sole crop only. Does not control *Acrachne racemosa, Commelina benghalensis*
Metolachlor	1.0-1 .5	Pre-emergence	Effective control of grasses	Suitable for intercropping
2,4-D	0.50-0.75	Post-emergence	Effective against broad-leaved weeds	For sole crop only. Apply between 4-6 weeks after planting. Good as sequential application to pre-emergence
Atrazine + pendimethalin	0.75 +0.75	Pre-emergence	Broad-spectrum weed control	For sole crop only
Atrazine + metolachlor	0.75 +0.50	Pre-emergence	Broad-spectrum weed control	For sole crop only

Pearl millet

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is the fourth most important food grain crop in India after rice, wheat and sorghum. Pearl millet can tolerate drought, low fertility, and high temperature. It is a summer annual crop well suited for double cropping and crop rotation. Pearl millet contains phytochemicals that lower cholesterol. It also contains folate, magnesium, copper, zinc, and vitamins E and B-complex. It is a sensitive crop concerning biotic & abiotic stresses; weeds are a major constraint. In India, the presence of weeds in general reduces crop yields by 31.5% in winter, 22.7% in summer and 36.5% in *Kharif* season and some cases can cause complete devastation of the crop (Rao and Nagamani, 2010).

Rajasthan (SKNAU, Jobner)

Management of *Cyperus rotundus* (Nut sedge) in pearl millet

Pearl millet is the major *Kharif* crop of Rajasthan. *Cyperus rotundus* (Motha) has become most problematic weed in Pearl millet. Atrazin as pre-emergence is already in recommendation for zone IIIA of Rajasthan but it is only controlling broad leaf weeds. Mainly narrow weeds are emerging out in the standing crop of pearlmillet. Managing narrow leaf weeds in standing crop of pearl millet, particularly *Cyperus rotundus* was very challenging because pearl millet itself is a narrow leaf crop, which belongs to the poaceae family.

Keeping these points in view, study was formulated to manage most problematic specific weed, *Cyperus rotundus* in pearl millet crop. The research trial was conducted under the RKVY sponsored project at the identified hot spots on the farmer's field in zone IIIA of Rajasthan.

In pearlmillet, minimum mean density of *Cyperus rotundus* was observed in deep summer ploughing followed by post-emergence application of tembotrione 100 g/ha (9.91 per sq.m.). Maximum Weed Control Efficiency (WCE) at 30 DAS and minimum Weed Index was observed in weed free, followed by deep summer ploughing + post-emergence application of tembotrione 100 g/ha (Table 6). Maximum mean grain and stover yield was recorded as 28.69 q/ha and 48.28 q/ha, respectively, under weed free. Among herbicide treatments, maximum mean grain and stover yield was recorded under deep summer ploughing + tembotrione 100 g/ha (PoE) treatment, followed by deep summer ploughing + metribuzin 0.75 kg/ha (PoE). Maximum net returns of Rs. 46,732 and BC ratio of 2.87 was recorded in deep summer ploughing + tembotrione 100 g/ha (PoE) (Table 7).

Table 6. Management of *Cyperus rotundus* (Motha) in pearl millet (*Kharif* 2017-19).

Treatments	Density (*Cyperus rotundus*) at 30 DAS (No./m²)				WCE at 30 DAS (Mean Basis)	WI (Mean Basis)
	2017	2018	2019	Mean		
Weedy check	57.25	49.43	63.43	56.70	0	34.76
Deep Summer Ploughing	45.00	43.08	50.85	46.31	18.33	31.09
T1 +2, 4 –D 2.0 kg/ha+Sugar (2%) as PoE	20.75	19.22	23.72	21.23	62.56	19.93
T1 +Tembotrione 100 g/ha as PoE	11.50	8.31	10.75	10.19	82.03	5.38
T1 +Metribuzin 0.75 kg/ha as PoE	17.75	16.86	18.36	17.66	68.86	14.19
T1 +Fenoxaprop-p-ethyl 750 kg/ha as PoE	18.50	17.57	21.83	19.30	65.96	20.07
Weed free (Cultural Control)	2.50	1.33	0.00	1.28	97.75	0.00
SEm±	1.31	1.29	2.32			
CD (P=0.05)	3.93	3.83	6.91			

Table 7. Effect of herbicides on yield and economics of pearl millet (*Kharif*, 2017-19).

Treatments	Grain Yield (q/ha)				Stover Yield (q/ha)				Net returns (₹/ha)	BC ratio
	2017	2018	2019	Mean	2017	2018	2019	Mean		
Weedy check	19.43	18.69	16.83	18.32	41.00	38.42	39.37	39.59	27694	1.64
Deep Summer Ploughing	20.55	19.16	18.33	19.35	42.50	41.32	40.23	41.35	30107	1.79
T_1 +2, 4 –D 2.0 Kg/ha+Sugar (2%) as PoE	24.10	22.13	21.22	22.48	45.25	44.18	42.62	44.02	35092	1.88
T_1 +Tembotrione 100 gm a.i/ha as PoE	28.80	26.24	24.66	26.57	48.25	45.46	47.75	47.15	42149	2.06
T_1 +Metribuzin 0.75 kg/ha as PoE	26.50	23.33	22.45	24.09	46.50	44.18	45.65	45.44	37798	1.94
T_1 +Fenoxaprop-P-ethyl 750 kg/ha as PoE	24.88	22.02	20.42	22.44	46.00	43.83	47.04	45.62	20483	0.61
Weed free (Cultural Control)	29.95	27.43	26.85	28.08	49.50	47.06	51.75	49.44	39885	1.52
SEm±	1.01	0.92	1.30		2.16	1.8	1.49			
CD (P=0.05)	2.99	2.72	3.86		6.42	5.34	4.41			

Deep summer ploughing followed by post emergence application of tembotrione 100 g/ha at 15-20 DAS is recommended for the control of *Cyperus rotundus* (Motha) weed in pearlmillet crop.

Weedy Check

Tembotrione 100 g/ha as PoE at 15-20 DAS

Effect of tembotrione on *Cyperus rotundus* in pearl millet crop

At Jaipur, PE application of atrazine 500 g/ha followed by PoE application of tembotrione 42% SC 100 g/ha at 3-4 leaf stage of weeds significantly controlled the weed population (WCE 93%) and increased pearl millet productivity (3.89 t/ha) under rainfed condition with maximum net returns (Rs 51430) and BC ratio (2.8).

Atrazine 500 g/ha as PE fb tembotrione 100 g/ha as POE at 15-20 DAS in pearl millet

At Jodhpur, the maximum grain yield (2194 kg/ha) was observed with the application of atrazine 50% WP at 500 g/ha (PE) *fb* one hand weeding at 30 DAS.

At Bikaner, tembotrione 42% SC at 120 g/ha at 3-4 leaf stage of weeds gave statistically similar benefit cost ratio as under pre-emergence application of atrazine at 400 g/ha followed by one weeding at 3-4 weeks after sowing.

Gujarat (AAU, Anand)

Weed flora: *Eleusine indica*, *Dactyloctenium aegyptium* and *Digitaria sanguinalis* in monocot weeds category whereas, *Digera arvensis, Trianthema monogyna* and *Boerhavia erecta* in dicot weed category and *Cyperus rotundus* in sedges category.

The farmers of middle Gujarat Agro-climatic zone growing summer pearl millet are advised to carry out IC and HW at 20 and 40 DAS or apply recommended atrazine 500 g/ha as pre-emergence for weed management. For minimizing phytotoxic effect of atrazine, better yield and nutrient status of soil, apply 10 t FYM/ha at the time of sowing in furrows.

Atrazine 500 g/ha PE

Atrazine 1000 g/ha PE

IC fb HW at 20 and 40 DAS

Haryana (CCSHAU, Hisar)

Weed management in pearl millet- chickpea cropping system

Due to limited irrigation facilities in South-western part of Haryana, pearl millet-chickpea/ mustard is one of the major cropping sequences for economic returns. Atrazine along with one hoeing is used to control weeds in pearl millet crop. To control weeds in chickpea, pendimethalin use has been found promising. Therefore, the feasibility of herbicide uses in both crops and its long-term effect on weed seed bank and soil micro flora was studied.

Weed flora of pearl millet consisted of *E. colona, Trainthema portulacastrum*, *Digera arvensis* and *Cyperus rotundus*. Data in table 8 revealed that application of atrazine provided excellent control of *T. portulacastrum* and *Echinochloa* but none of the treatment was effective against *C. rotundus*. Weed biomass was least in mechanical weeded plots followed by atrazine 0.75 kg/ha *fb* 2,4-D 0.5 kg/ha. Highest grain yield (2520 kg/ha) of pearl millet was recorded in mechanical weeded plots which was at par with atrazine 0.75 kg/ha *fb* 2,4-D 0.5 kg/ha and atrazine at 1.0 kg/ha as pre-emergence. Presence of weeds throughout the season resulted in 43.8 % decrease in grain yield of pearl millet in 2007 (Table 8).

Table 8. Weed density and biomass of pearl millet as affected by weed control treatments.

Treatment	Density of weeds/m^2 at 30 DAS				Weed biomass (q/ha)	Grain yield (kg/ha)
	T. portulacastrum	*E. colona*	*D. arvensis*	*C. rotundus*	30 DAS	
Weedy Check	70	159	3	40	93.1	1416
Mechanical weeding (Two)	0	4.2	0	14	1.57	2520
Atrazine 0.75 kg/ ha P.E.	8	6.0	2	42	37.2	2225
Atrazine 1.0-kg/ ha P.E.	6	7.5		72	22.4	2270
Atrazine 0.75 kg/ ha *fb* 2,4-D 0.5 kg/ha	0	1.0	0	11	2.42	2450
CD (P=0.05)	-	-	-	-	1.2	83

Uttarakhand (GBPUAT, Pantnagar)

In Uttarakhand, weeds can be managed by herbicides (Table 9) in sole crop of pearl millet.

Table 9. Herbicides recommended for millets.

Name of the crop	Name of the Herbicides	Dose (kg/ ha)	Time of application	Weeds controlled	Remarks
Pearl millet	Atrazine	0.50	Pre-emergence/ early post emergence	*Trianthema portulacastrum and E. colona*	For sole crop only
	2,4-D	0.50-0.75	Post-emergence	Effective against broad -leaved weeds	For sole crop only. Apply between 4-6 weeks after planting Good as sequential application to pre-emergence
	Pendimethalin	0.50-0.75	Pre-emergence	Broad-spectrum weed control	Each supplemented with one hand weeding at 45 days after supply
	Oxadiazone	1.0	Pre-emergence		

Finger millet

Finger millet [*Eleusine coracana* (L.) Gaertn] is an important coarse cereal of tropical climate grown mostly under rainfed and risky conditions during the monsoon season in arid and semi-arid regions of India. It ranks third in importance among millets in the country after sorghum and pearl millet. It is cultivated in a wide range of environments and growing conditions. In India, minor millets share an area of 0.44 million ha with a production of 0.34 million tonnes and among the minor millets, finger millet occupies larger area under cultivation. In India, the crop occupies a share of 1.15 million hectares in terms of area with a production of 1.99 million tonnes and productivity of 1724 kg/ha respectively. Among different production constraints of finger millet, weed menace poses serious problems. Generally, millets are relatively poor competitors for growth resources than weeds, especially during the early stages of the crop. This severe competition due to uncontrolled weeds may result in drastic reduction in the yield up to 34 to 61% in finger millet depending on crop cultivars, nature and intensity of weeds, spacing, duration of weeds infestation, management practices and environmental conditions (Nanjappa and Hosamani 1985 and Mishra *et al*. 2018).

Karnataka, (UAS, Bengaluru)

Effect of weed management practices with fertility levels on weed shift and economics in finger millet-groundnut cropping system in the eastern dry zone of Karnataka

Weed flora: The major weed species in finger millet were *Cyperus rotundus*, (sedge), *Cynodon dactylon*, *Digitaria marginata*, *Dactyloctenium aegyptium*, *Echinochloa colona* (among grasses), *Commelina benghalensis*, *Euphorbia geniculata*, *Ageratum conyzoides*, *Borreria articularis*, *Amaranthus viridis* and *Acanthospermum hispidum* (among broad-leaved weeds).

After sixteen years of detailed study, continuous application of butachlor has brought down the grass density substantially from 74.4/m^2 in 1999 to 13.3/m^2 in 2014. Similarly, the application of 2, 4-D sodium salt has reduced the broad-leaved weed density from 36.4/m^2 in 1999 to 2.8/m^2 in 2014. Continuous removal of weeds by manual weeding reduced the weed density of all three categories very effectively from a total weed count of 130.4/m^2 in 1999 to 14.1/m^2 in 2014.

Over nine years (1999 to 2007), the grain yield obtained in finger millet applied with fertilizer alone gave a yield (3263 kg/ha) similar to finger millet receiving both fertilizer and FYM (3216 kg/ha). Among weed control treatments, grain yield obtained in plot treated with butachlor (3533 kg/ha) was similar to hand weeding twice (3395 kg/ha) and these were significantly superior to 2,4-D (2791 kg/ha) owing to good control of grasses, as the later treatment was effective on broad-leaved weeds. Butachlor and hand weeding treatments gave higher grain yield at both sources of fertility than 2,4-D treatment (Fig 1).

Whereas, grain yield of finger millet over five years (2010 to 2014) applied with fertilizer alone gave a yield (3120 kg/ha) which was on par with the finger millet receiving both fertilizer and FYM (3070 kg /ha). Among weed control treatments, grain yield obtained in plot treated with butachlor (3120 kg /ha) was similar to hand weeding twice (3520 kg /ha) and these were significantly superior to 2, 4-D sodium salt (2630 kg/ha) owing to good control of grasses, as the later treatment was effective on broad leaf weeds. Butachlor and hand weeding treatments gave higher grain yield at both sources of fertility than 2, 4-D sodium salt treatment.

Among weed management practices, over sixteen years, the use of herbicide butachlor 0.75 kg/ha – 3 DAP was relatively better in controlling grasses and gave a yield higher than the plot treated with 2,4-D sodium salt 0.75 kg/ha (15 DAP) and was similar to hand weeding. Butachlor was effective in suppressing the grasses which were the competitors with finger millet for critical growth resources during the critical period of crop weed competition of finger millet. Although 2,4 -D sodium salt was effective against broad leaf weeds and sedges, grasses emerged in large density and suppressed the growth of finger millet crop.

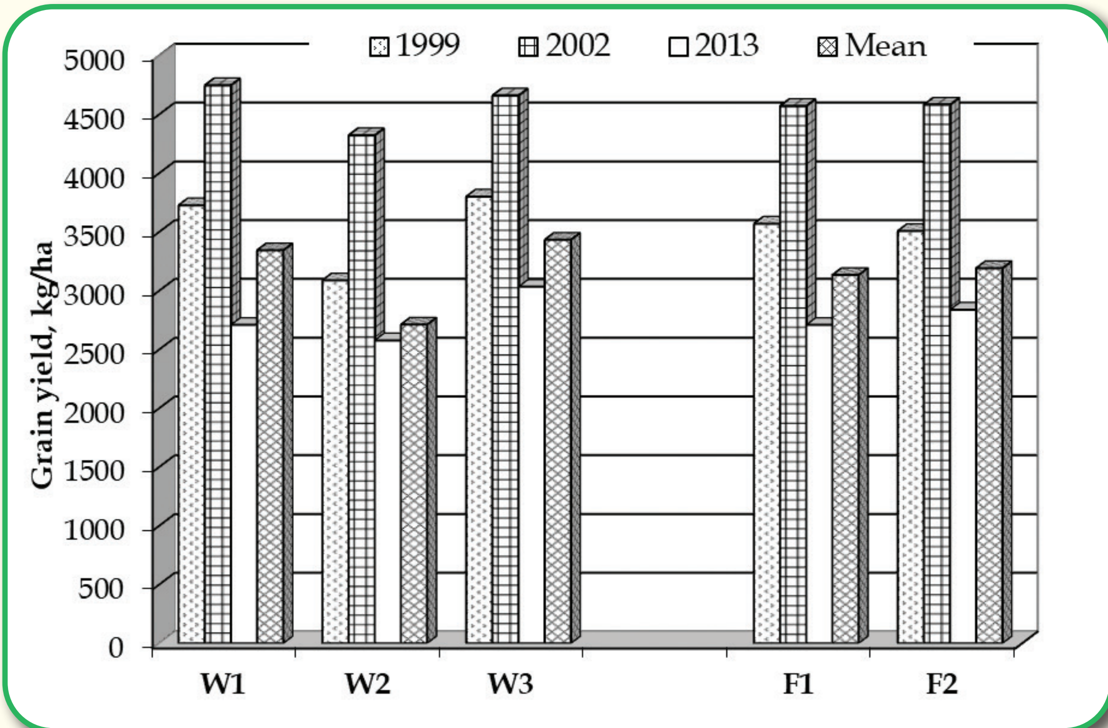


Fig.1. Continuous effect of weed control treatments and fertility sources on grain yield (kg/ha) (kharif 1999, 2002, 2013 and mean of fifteen years) in transplanted finger millet at Hebbal, UAS, Bengaluru (For treatment details, refer Table 10)

Table 10: Economics of weed management practices followed in finger millet, during *Kharif*, 2013 in finger millet-groundnut cropping system at Hebbal, UAS, Bangalore.

Finger millet		
Treatments	Cost of Weed Management (Rs/ha)	Savings Over Hand Weeding (Rs/ha)
Butachlor 50 EC 0.75 kg /ha	850	6350
2,4-D Na salt 80 WP 0.75 kg /ha	750	6450
Hand Weeding (20 & 45 DAP)	7200	--

Cost of herbicides: Butachlor 50 EC Rs. 225/- litre, 2, 4-D sodium salt 80 WP - Rs. 250/- per kilogram, Application cost – Rs. 500/- per ha, Cost of labour – Rs. 150/- (for men) and Rs. 130/- (for women) per day of eight hours work

Integrated weed management in dry-seeded finger millet

Weed flora: The major weed species found in the crops were, in grasses- *Cynodon dactylon*; *Dactyloctenium aegyptium*; *Digitaria marginata*, *Echinochloa colona*; *Eleusine indica*; broad leaf weeds: *Alternanthera sessilis*; *Lonadium supfruiticesum*; *Borreria hispida*; *Catharanthus pusillus*; *Achyranthes aspera*; *Commelina benghalensis*; *Celosia argentea*; *Vinca puscilla* ; *Cleome viscose*; *Amaranthus viridis* and *Acanthospermum hispida*, sedges population was very less. Broad leaf weeds dominated followed by narrow leaf weeds

Herbicide application exhibited profound influence on germination and plant stand of ragi crop (Table 11). Pre-emergent application of different herbicides at different doses had phytotoxicity effect. Butachlor 50 EC at 750 and 1000 g/ha and pendimethalin 38.7 CS at 700 and 1000 g/ ha only 50 per cent germination was noted, while other 50 per cent germinated seedlings showed discoloration and destruction of crop. While in bensulfuron methyl 0.6 + pretilachlor 6.0 G at 330 and 450 g /ha 15- 20 percent germination failure, some stand loss, stunting, discoloration was pronounced till 20 days after herbicide spray (Table 12). Later at new flush, crop was recovered and 60 per cent plant stand was observed with more number of tillers per plant compared to non-herbicide treated plot.

Plots treated with mechanical method of weed recorded highest yield (27.33 q/ha). The yield obtained in bensulfuron methyl 0.6 + pretilachlor 6.0 G at 330 and 450 g /ha though showed phytotoxic, recorded highest yield (19.57 q/ha) among other herbicide treated plots. Unweedy check recorded lowest yield (15.63 q/ha).

The pre-emergent herbicides butachlor 50 EC at 750 and 1000 g/ha and pendimethalin 38.7 CS at 700 and 1000 g/ ha phytotoxicity was observed. In bensulfuron-methyl 0.6 + pretilachlor 6.0 G at 330 and 450 g/ha treated plots 20 per cent crop stand loss was observed. Though all the herbicides gave effective weed control over weedy check, the above herbicides could not be recommended at field level as it caused phytotoxicity and crop stand loss was noted.

Intercultivation 25 + hand weeding 45 DAS

Mechanical weeding at 20 and 40 DAS

Bensulfuron methyl 0.6 + pretilachlor 6.0 G -330g/ha

Bensulfuron methyl 0.6 + pretilachlor 6.0 G-450g/ha

Effect of pre-emergent herbicide bensulfuron methyl + pretilachlor on ragi in comparison with mechanical method of weed control

Table 11. Crop toxicity ratings as influenced by different herbicides in integrated weed management in dry seeded ragi.

Effect	Rating	Weed	Crop
None	0	No control	No injury, normal
Slight	1	Very poor control	Slight stunting, injury or discolouration
	2	Poor control	Some stand loss, stunting or discolouration
	3	Poor to deficient control	Injury more pronounced but not persistent
Moderate	4	Deficient control	Moderate injury, recovery possible
	5	Deficient to moderate control	Injury more persistent, recovery doubtful
	6	Moderate control	Near severe injury no recovery possible
Severe	7	Satisfactory control	Severe injury stand loss
	8	Good control	Almost destroyed a few plants surviving
	9	Good to excellent control	Very few plants alive
Complete	10	Complete control	Complete destruction

0-No crop destruction of crop: 10 Complete destruction of crop

Table 12. Qualitative description of treatment effects on weeds and crop in the visual scoring scale of 0 to 10

Pre-Emergence Treatments	Dose (g/ha)	Crop Toxicity Rating (DAHS)*										
		0	1	3	5	7	10	15	18	20	25	30
Butachlor 50 EC	750	8	8	8	10	10	10	10	10	10	10	10
Butachlor 50 EC	1000	8	8	8	10	10	10	10	10	10	10	10
Bensulfuron methyl 0.6 + pretilachlor 6.0 G	330	1	1	2	2	2	3	4	4	4	0	0
Bensulfuron methyl 0.6 + pretilachlor 6.0 G	450	1	1	2	2	2	3	4	4	4	0	0
Pendimethalin 38.7 CS	700	10	10	10	10	10	10	10	10	10	10	10
Pendimethalin 38.7 CS	1000	10	10	10	10	10	10	10	10	10	10	10
Intercultivation at 25 DAS + one HW at 45 DAS	--	0	0	0	0	0	0	0	0	0	0	0
Mechanical weeding at 20 and 40 DAS	---	0	0	0	0	0	0	0	0	0	0	0
Untreated control	---	0	0	0	0	0	0	0	0	0	0	0

Bioefficacy evaluation of different herbicides under different establishment methods of ragi

Among the pre-emergent herbicides atrazine 50 WP 250 g/ha and pendimethalin 38.4% + pyrazosulfuron ethyl 0.85% ZC 400 and 785 g/ha did not show any crop phytotoxicity and controlled weeds effectively till 40 days. Plots treated with early post emergent herbicides, chlorimuron ethyl 25% WP at 6 and 9 g/ha metribuzin 70 % WP 350 and 525 g/ha , bentazone 48 Sl 986 g/ha and penoxsulam 2.67 20 g/ha did not show any crop toxicity, while other herbicides showed crop toxicity ranging from severe injury to completer crop destruction (Table 13 and 14).

Table 13. Crop toxicity ratings as influenced by different herbicides in ragi during *Kharif* 2022 at UAS, GKVK, Bengaluru.

Treatments	% a.i	Dose /ha	Crop Toxicity Ratings (Days after herbicide application)										
Pre-emergent herbicide (Direct sown ragi)			**0**	**1**	**3**	**5**	**7**	**10**	**15**	**18**	**20**	**25**	**30**
Atrazine	50	250	0	0	0	0	0	0	0	0	0	0	0
Pendimethalin 38.4% + pyrazosulfuron ethyl 0.85% ZC	39.25	400	0	0	0	0	0	0	0	0	0	0	0
Pendimethalin 38.4% + pyrazosulfuron ethyl 0.85% ZC	39.25	785	0	0	0	0	0	0	0	0	0	0	0
Post emergent herbicides (Transplant Ragi)													
Chlorimuron ethyl 25% WP	25	6	0	0	0	0	0	0	0	0	0	0	0
Chlorimuron ethyl 25% WP	25	9	0	0	0	0	0	0	0	0	0	0	0
Metribuzin 70%WP	70	350	0	0	0	0	0	0	0	0	0	0	0
Metribuzin 70%WP	70	525	0	0	0	0	0	0	0	0	0	0	0
Propaquizafop 10% EC	10	50	0	1	3	3	5	8	9	10	10	10	10
Propaquizafop 10% EC	10	100	0	1	3	3	5	8	9	10	10	10	10
Bentazone 48 SL	48	960	0	0	0	0	0	0	0	0	0	0	0
Penoxsulam 2.67	2.67	20	0	0	0	0	0	0	0	0	0	0	0
Fenoxaprop - p- ethyl 9.3% EC	9.3	56	0	1	3	3	5	8	9	10	10	10	10
Penoxsulam 1.02% + cyhalofop-butyl 5.1% OD	6.1	120	0	1	3	3	5	8	9	10	10	10	10
Imazethapyr 10 SL	10	1000	0	1	2	3	5	8	9	10	10	10	10
Imazethapyr 10 SL	10	750	0	1	2	3	5	8	9	10	10	10	10
Tembotrione 42 % SC	42	120	0	3	4	5	8	9	10	10	10	10	10
Topramezone 33.6% SC	33.6	25.2	0	3	4	5	8	9	10	10	10	10	10
Fluazifop -p- butyl 11.1 % w/w + fomesafen 11.1% SL	22.2	250	0	3	3	4	8	9	10	10	10	10	10
Fluazifop -p- butyl 11.1 % w/w + fomesafen 11.1% SL	22.2	500	0	3	4	5	8	9	10	10	10	10	10
Sodium acifluorfen 16.5% + clodinafop propargyl 8% EC	24.5	245	0	3	4	5	8	9	10	10	10	10	10

0-No injury, Normal; 1- Injury; 10 – complete destruction

PE- Pendi + Pyrazosulfuron 785 g/ha

PE- Pendi + Pyrazosulfuron 400 g/ha

PE- Atrazine 250 g/ha

Phytotoxicity of PE-Herbicide in ragi

Table 14. Weed toxicity ratings as influenced by different herbicides in ragi during *Kharif* 2022 at UAS, GKVK, Bengaluru.

Treatments	% a.i	Dose (g ha)	Weed control ratings (Days after herbicide spray)										
Pre-emergent herbicide (Direct sown ragi)			**0**	**1**	**3**	**5**	**7**	**15**	**18**	**15**	**20**	**25**	**30**
Atrazine	50	250	6	6	6	6	6	6	8	8	9	9	10
Pendimethalin 38.4% + pyrazosulfuron ethyl 0.85% ZC	39.25	400	6	6	6	6	8	8	9	9	10	10	10
Pendimethalin 38.4% + pyrazosulfuron ethyl 0.85% ZC	39.25	785	6	6	6	6	8	8	9	9	10	10	10
Post-emergent herbicides (Transplant Ragi)													
Chlorimuron Ethyl 25% WP	25	6	6	6	6	6	7	7	7	8	8	8	8
Chlorimuron Ethyl 25% WP	25	9	6	6	6	7	7	7	7	8	8	8	8
Metribuzin 70%WP	70	350	6	6	6	6	7	7	7	8	8	8	8
Metribuzin 70%WP	70	525	6	6	6	7	7	7	7	8	8	8	8
Propaquizafop 10% EC	10	50	6	6	6	7	7	7	7	8	8	8	8
Propaquizafop 10% EC	10	100	6	6	6	7	7	7	7	8	8	8	8
Bentazone 48 SL	48	960	6	6	6	6	6	7	7	8	8	8	8
Penoxsulam 2.67	2.67	20	6	6	6	6	7	8	8	9	9	9	9
Fenoxaprop - p- ethyl 9.3% EC	9.3	56	6	6	6	7	7	7	8	8	8	8	8
Penoxsulam 1.02% + cyhalofop -butyl 5.1% OD	6.1	120	6	6	6	6	7	7	8	8	8	8	8
Imazethapyr 10 SL	10	1000	6	6	6	6	7	7	7	8	8	8	8
Imazethapyr 10 SL	10	750	0	1	2	3	5	8	9	10	10	10	10
Tembotrione 42 % SC	42	120	0	3	4	5	8	9	10	10	10	10	10
Topramezone 33.6% SC	33.6	25.2	0	3	4	5	8	9	10	10	10	10	10
Fluazifop -p- butyl 11.1 % w/w + fomesafen 11.1% SL	22.2	250	0	3	3	4	8	9	10	10	10	10	10
Fluazifop -p- butyl 11.1 % w/w + fomesafen 11.1% SL	22.2	500	0	3	4	5	8	9	10	10	10	10	10
Sodium acifluorfen 16.5% + clodinafop Propargyl 8% EC	24.5	245	0	3	4	5	8	9	10	10	10	10	10

0-No injury, Normal; 1- Injury; 10 – complete destruction

Chlorimuron ethyl 25 WP 6 g/ha

Metribuzin 70 WP 525 g/ha

Bentazone 48 Sl 960 g/ha

Penoxsulam 2.67 20 g/ha

Tembotrione 42 % SC 120 g/ha

Fluazifop -p- butyl 11.1 % w/w + Fomesafen 11.1% SL 500 g/ha

Sodium Acifluorfen 16.5% + Clodinafop propargyl 8% EC 245 g /ha

Topramezone 33.6 % SC 25.2 g /ha

Phytotoxicity of POE-herbicide toxicity in ragi

Weed management in direct seeded /drill sown finger millet

Crop toxicity ratings

Between the two pre-emergent herbicide, application of atrazine 500 g/ha showed delay in germination of ragi seeds up to 18 days after herbicide spray. However, the crop seeds germinated fully after 25 days after herbicide spray and no further phyto-toxicity was observed on the new flush of crop growth (Table 15).

Weed flora

Major weed flora found in the experimental plots was sedges- *Cyperus rotundus*, Grasses–*Eleusine indica*, *Digitaria marginata* and *Cynodon dactylon*. Among broad-leaved weeds–*Borreria hispida*, *Ageratum conyzoides*, *Commelina benghalensis*, *Celosia argentea*, *Oldenlandia corymbosa*, *Achyranthus aspera* and *Alternanthera sessilis*. Among the different categories of weeds broad-leaved weeds dominated the weed flora followed by grasses and sedges.

Weed Control Efficiency (%)

At 20 DAS, atrazine 500g/ha as PE *fb* metsulfuron methyl + chlorimuron ethyl 4 g/ha as PoE and atrazine 500 g/ha as PE treatment recorded the highest WCE of 78.34 % and 70.05%, respectively whereas even at 40 DAS, atrazine 500 g/ha as PE *fb* metsulfuron methyl + chlorimuron ethyl 4 g/ha as PoE recorded the highest WCE of 67.84% followed by two HW at 20 and 40 DAS (67.41%), while at later stages two HW at 20 and 40 DAS (53.13%) and atrazine 500g/ha as PE *fb* 2,4-D sodium salt 800 g/ha as PoE (47.43%) recorded the highest WCE compared to other treatments.

Yield and yield attributes of finger millet:

Among the yield parameters only the number of productive tillers per plant showed the significant differences between the treatments. Two HW at 20 and 40 DAS (3.87) followed by atrazine 500g/ha as PE *fb* metsulfuron methyl + chlorimuron ethyl 4 g/ha as PoE (3.27) were the superior treatments compared to other treatments. With respect to number of fingers in ear head and finger length there was no significant differences between the treatments.

The two hand weeding at 20 DAS and 40 DAS significantly recorded the highest grain yield of 1.85 t/ha. Atrazine 500 g/ha as PE *fb* metsulfuron methyl + chlorimuron ethyl 4 g/ha as PoE (1.78 t/ha) was on par with the above treatment. This might be due to better control of weeds in these treatments which resulted in higher number of productive tillers per plant, number of fingers per head and finger length and in-turn all these together contributed to get the highest yield.

Weed index / weed competition index:

The weed index was higher in unweeded check (52.13%) and among the weed management practices, atrazine 500 g/ha as PE (46.53%) and pyrazosulfuron-ethyl 15g/ha as PE (45.60%) recorded the highest weed index due to poor control of weeds in latter stages of crop growth, which in-turn resulted in lower yield. The treatment atrazine 500 g/ha as PE *fb* metsulfuron methyl + chlorimuron ethyl 4 g/ha as PoE (0.53%) recorded the lowest weed index indicating that these treatments were effective in controlling weeds and produced on par yield of hand weeding.

Economics:

Highest net return was obtained in atrazine 500 g/ha as PE *fb* metsulfuron methyl + chlorimuron ethyl 4 g/ha (Rs 36,960 Rs/ha) followed by atrazine 500g/ha as PE *fb* 2,4-D sodium salt 800 g/ha as PoE (Rs 35,562/ha) and two hand weeding at 20 DAS and 40 DAS (Rs 34,792/ha).

The benefit cost ratio was highest in atrazine 500 g/ha as PE *fb* metsulfuron methyl + chlorimuron ethyl 4 g/ha (2.45) followed by atrazine 500 g/ha as PE *fb* 2,4-D sodium salt 800 g/ha as PoE (2.38) and pyrazosulfuron-ethyl 15g/ha as PE *fb* metsulfuron methyl + chlorimuron ethyl 4 g/ha as PoE (2.36). However lowest BC ratio was recorded in weedy check (1.28), pyrazosulfuron-ethyl 15g/ha as PE (1.87) and atrazine 500 g/ha as PE (1.97). Under the treatments where only pre- emergent herbicides were applied weeds were less at early stages of crop, as the days pass the weeds grow profusely due to absence of any weed control measures.

Recommendation:

Among the chemical method of weed control in finger millet, two hand weeding at 20 DAS and 40 DAS was the best and almost comparable with atrazine 500 g/ha as PE *fb* metsulfuron methyl + chlorimuron ethyl 4 g/ha, atrazine 500 g/ha as PE *fb* 2,4-D sodium salt 800 g/ha and pyrazosulfuron-ethyl 15g/ha as PE *fb* metsulfuron methyl + chlorimuron ethyl 4 g/ha as PoE were found to be effective in controlling weeds.

Table 15. Crop toxicity ratings as influenced by different herbicides in direct-seeded / drill sown finger millet – 2022 at UAS, GKVK, Bengaluru.

Treatments	Dose	Crop Toxicity Rating (DAHS)*										
	g/ha	0	1	3	5	7	10	15	18	20	25	30
Pyrazosulfuron-ethyl 15 g/ha as PE	15	0	0	0	0	0	0	0	0	0	0	0
Atrazine 500 g/ha as PE	500	0	0	0	8	8	8	7	5	0	0	0
Pyrazosulfuron-ethyl 15 g/ha as PE *fb* 2,4-D sodium salt 800 g/ha as PoE	15	0	0	0	0	0	0	0	0	0	0	0

Treatments	Dose g/ha	Crop Toxicity Rating (DAHS)*										
		0	1	3	5	7	10	15	18	20	25	30
Atrazine 500 g/ha as PE *fb* 2,4-D sodium salt 800 g/ha as PoE	500	0	0	0	8	8	8	7	5	0	0	0
Pyrazosulfuron-ethyl 15 g/ha as PE *fb* metsulfuron methyl + chlorimuron ethyl 4 g/ha as PoE	15	0	0	0	0	0	0	0	0	0	0	0
Atrazine 500 g/ha as PE *fb* metsulfuron methyl + chlorimuron ethyl 4 g/ha as PoE	500	0	0	0	8	8	8	7	5	0	0	0
2 HW at 20 and 40 DAS	-	0	0	0	0	0	0	0	0	0	0	0
Weedy check	-	0	0	0	0	0	0	0	0	0	0	0

*DAHS- Days after Herbicide spray 0-No injury, Normal; 1- Injury; 10 – complete destruction

Odisha (OUAT, Bhubaneswar)

In Odisha, finger millet is grown and consumed by the indigenous people for a long time and it is the major millet grown in the state covering around 86% of the total millets area (53,230 ha) of the state. The research on chemical weed management in finger millets is very meager; therefore, field studies were conducted to find out suitable chemical method to manage the weeds so as to realize the higher yield potential of the crop.

- The predominant weed flora observed in the experimental site were *Echinochloa crusgalli*, *Dactyloctenium aegyptium* and *Eleusine indica* among grasses, *Cyperus rotundus* and *Cyperus iria* among sedges, *Commelina benghalensis*, *Ageratum conyzoides*, *Oldendandia corymbosa* among broad-leaved weeds.
- Pre-emergence application of bensulfuron methyl + pretilachlor 0.660 kg/ha at 2 DAT *fb* 2,4 D Ethyl Ester 0.50 kg/ha 30 DAT significantly reduced the weed population and dry matter production(g/m^2).
- The yield of finger millet was higher in case of application of bensulfuron methyl + pretilachlor 0.660 kg/ha at 2 DAT *fb* 2,4 D Ethyl Ester 0.50 kg/ha 30 DAT (2.86 t/ha) in comparison to other treatments. The highest B:C (2.24) was also realized with this treatment (Table 16).
- Application of the ready mix herbicide bensulfuron methyl + pretilachlor (RM) 0.660 kg/ha at 2 days after transplanting (DAT) followed by 2, 4 D ethyl ester 0.50 kg/ha at 30 DAT was found to be the best combination of herbicides in controlling the mixed weed populations in the transplanted finger millet with a weed control efficiency of (86%).

Table 16. Performance of weed management options in finger millet.

Treatment	Weed density (No./m^2)			Weed biomass (g/m^2)			Yield (t/ha)	Net Returns (Rs/ha)	B:C
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS			
Mechanical weeding at 20 DAS	9.45 (89.00)	13.88 (192.33)	9.15 (83.67)	8.62 (74.00)	8.87 (78.28)	4.21 (17.32)	2.02	18742	1.51
Pre-emergence application of bensulfuron methyl + pretilachlor 0.660 kg/ha at 2 DAT	6.03 (36.00)	7.14 (50.67)	6.08 (36.67)	9.30 (86.00)	2.62 (6.38)	1.63 (2.16)	2.36	24651	1.64

Treatment	Weed density (No./m^2)			Weed biomass (g/m^2)			Yield (t/ha)	Net Returns (Rs/ha)	B:C
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS			
Pre-emergence application of pendimethalin 0.75 kg/ha at 2 DAT *fb* 2, 4-D Ethyl Ester 0.50 kg/ha 30 DAT	5.81 (33.33)	6.65 (44.00)	5.54 (30.33)	8.95 (79.67)	2.42 (5.37)	1.46 (1.64)	2.48	26351	1.77
Pre-emergence application of pretilachlor 0.625 kg/ha at 2 DAT *fb* 2, 4-D Ethyl Ester 0.50 kg/ha 30 DAT	4.69 (21.67)	5.80 (33.33)	4.10 (16.33)	7.00 (49.67)	2.07 (3.81)	1.17 (0.87)	2.71	27514	1.88
Pre-emergence application of bensulfuron methyl + pretilachlor 0.660 kg/ha at 2 DAT *fb* 2,4 D Ethyl Ester 0.50 kg/ha 30 DAT	4.29 (18.00)	5.36 (28.33)	3.45 (11.67)	5.86 (34.00)	1.88 (3.03)	1.08 (0.67)	2.86	32654	2.24
SE(m)±	0.11	0.19	0.11	0.08	0.11	0.08	0.15	-	-
CD (P=0.05)	0.34	0.58	0.34	0.24	0.34	0.24	0.46	-	-

Bensulfuron methyl + pretilachlor 0.660 kg/ ha fb 2,4 D EE 0.50 kg/ ha

Weedy check

Chhattisgarh (IGKV, Raipur)

Weed management in direct-seeded finger millet (*Kharif* 2022)

The experimental field was infested with *Echinochloa colona*, *Alternanthera sesillis*, *Celosia argentea*, *Cyperus iria*, *Physalis minima*, *Cyanotis axillaris* and *Dinebra retroflexa*.

Different weed management practices had their significant influence on reducing the weed biomass and enhancing the weed control efficiency, yield attributes and grain yield of direct drill seeded finger millet. Atrazine 500 g/ha as PE *fb* 2, 4-D sodium salt 800 g/ha as PoE produced the lowest weed biomass and achieved highest WCE (43.53% at 60 DAS) with highest grain yield (1.96 t/ha) and net return over the other weed management practices. Atrazine 500 g/ha as PE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE has also found to be comparable in terms of producing grain yield and net returns (Table 17).

Table 17. Weed biomass, WCE% at 60 DAS, no. of fingers/ tiller, finger weight/ plant (g), grain yield (t/ha) and net return as influenced by weed management practices in direct drill sown finger millet (2022).

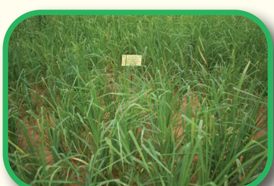
Treatment	Weed biomass (m^2)	WCE%	No. of fingers / tiller	Finger weight/ plant (g)	Grain yield (t ha)	Net returns (Rs/ ha)
Pyrazosulfuron-ethyl 15 g/ha as PE	8.52 (72.10)	26.82	5.87	5.57	1.68	32574
Atrazine 500 g/ha as PE	8.41 (70.31)	28.64	6.67	5.57	1.75	35069
Pyrazosulfuron-ethyl 15g/ha as PE *fb* 2, 4-D sodium salt 800 g/ha as PoE	8.32 (68.72)	29.93	6.87	5.59	1.78	34811
Atrazine 500 g/ha as PE *fb* 2, 4-D sodium salt 800 g/ha as PoE	7.49 (55.64)	43.53	8.53	8.50	1.96	41241
Pyrazosulfuron-ethyl 15 g/ha as PE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	8.28 (68.03)	30.24	7.07	5.60	1.78	34784
Atrazine 500 g/ha as PE *fb* metsulfuron-methyl + chlorimuron-ethyl 4 g/ha PoE	8.17 (66.21)	32.80	7.53	7.69	1.95	40857
2 HW at 20 & 40 DAS	3.09 (9.04)	30.96	7.47	7.33	1.93	29079
Weedy check	9.95 (98.53)	0.00	4.93	5.09	0.75	259
CD (P=0.05)	0.83	-	1.96	1.78	0.45	-

Atrazine 500 g/ha as PE *fb* 2,4-D sodium salt 800 g/ha as PoE

Pyrazosulfuron-ethyl 15g/ha as PE *fb* 2,4-D sodium salt

2 Hand weeding at 20 and 40 DAS

Pyrazosulfuron-ethyl 15g/ha as PE *fb* metsulfuron methyl + chlorimuron ethyl 4 g/ha as PoE



Atrazine 500 g/ha as PE *fb* metsulfuron methyl + chlorimuron ethyl 4 g/ha as PoE

Weedy check

Pyrazosulfuron-ethyl 15 g/ha as PE

Atrazine 500g/ha as PE

Direct seeded/ drill sown finger millet at 30 DAS with different treatments

10 DAHS - After the Application of Atrazine (PE)

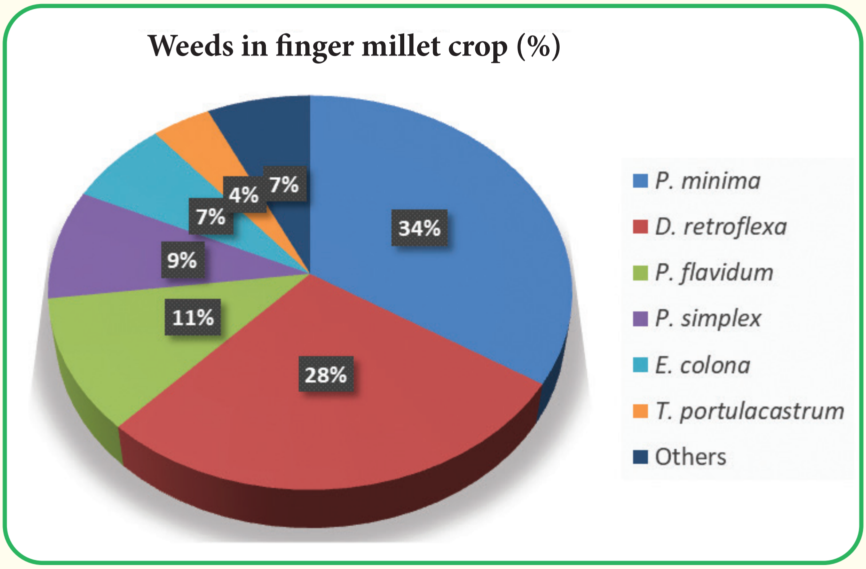
10 DAHS - After the Application of Pyrazosulfuron-ethyl (PE)

General view of the experiment

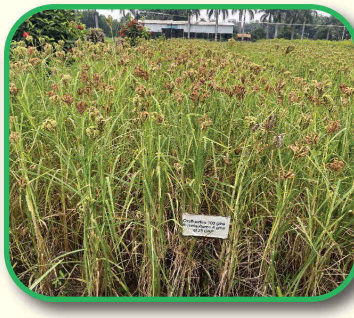
Overview of the initial establishment of the crop

Madhya Pradesh (ICAR-Directorate of Weed Research, Jabalpur)

Weed management in transplanted finger millet



- Application of 2 HW, oxyfluorfen 100 g/ha *fb* 1 HW, pyrazosulfuron-ethyl 20 g/ha *fb* 1 HW and oxyfluorfen 100 g/ha *fb* metsulfuron 4 g/ha recorded higher weed control efficiency (WCE) of 86.1, 65.3, 55.7 and 53.7%, respectively at 30 DAS.
- Highest WCE of 92.9, 91.4,90.1, 89.9 and 87.6% was recorded by application of pyrazosulfuron-ethyl 20 g/ha *fb* 1 HW, atrazine 750 g/ha *fb* 1 HW, 2 HW, oxyfluorfen 100 g/ha *fb* 1 HW and oxyfluorfen 100 g/ha *fb* metsulfuron 4 g/ha, respectively at 60 DAS.
- Highest grain yield of 3.91 t/ha was obtained from oxyfluorfen 100 g/ha *fb* 1 HW which was significantly similar to all other treatments except atrazine 750 g/ha *fb* metsulfuron 4 g/ha and unweeded check. Grain yield was reduced by 44.5% under unweeded check.
- Higher B:C was recorded under treatments oxyfluorfen 100 g/ha *fb* 1 HW (3.28), oxyfluorfen 100 g/ha *fb* metsulfuron 4 g/ha (3.27), metribuzin 150 g/ha *fb* metsulfuron 4 g/ha (3.18) and atrazine 750 g/ha *fb* 1 HW (3.08).



Telangana, (PJTSAU, Hyderabad)

Bio-efficacy and phytotoxicity of herbicides and herbicide mixtures for weed control in finger millet.

The germination of the crop totally failed in all the three herbicides i.e., oxyfluorfen, oxadiargyl and bensulfuron methyl + pretilachlor compared to control. The same trial was repeated at another site and the PE herbicides were applied on the next day of sowing at their X dose and 0.5 X dose described in the treatments. Total failure of the finger millet germination was recorded even at 0.5 X dose along with X dose and the trial was discontinued.

Kodo Millet

Kodo millet (*Paspalum scrobiculatum* (L.) P. Beauv) is an important minor millet. Kodo Millet is extensively grown on the poorest soil in the whole of India. It is extremely hard, drought-resistant, and reputed to grow on rocky or gravelly soils. It requires less rainfall. It is rich in nutrient content in terms of higher protein, dietary fiber and lesser fat content. This grain is recommended as a substitute for rice to the patients suffering from diabetes. The crop has high yielding potentiality but its productivity is comparatively low. One of the major reasons for the poor performance of kodo millet is inadequate weed management practices. Due to slow initial growth, it faces heavy weed competition right from the early crop growth stages. Uncontrolled weeds may reduce yield by 55-61 per cent.

Karnataka (UAS, Bengaluru)

Evaluation of Pre- emergent herbicide in kodo millet

Crop toxicity rating:

The data on crop toxicity rating are presented in Table 18. Among the various herbicides evaluated, PE application of bensulfuron methyl 0.6 G +pretilachlor 6.0 G 6.6 EC at 165 g/ha and 330 g/ha and pendimethalin 38.7 CS at 680 g and 1000 g/ha, no crop toxicity was observed.

In plots treated with oxadiargyl 80 WP at both the dose 50 and 75 g/ha there was delay in germination compared to other treatments and crop toxicity was observed only at initial stages, later crop recovered. In butachlor 50 EC applied plots 750 g/ha and 1000 g/ha only 40-50 per cent germination was recorded and plant stand was very poor. In atrazine treated plot, at higher dose 500 g/ha early crop toxicity (7 DAHS) was observed compared to lower dose 250 g/ha (toxicity was observed at 10 DAHS). Leaf burning was observed which pronounced, became persistent; no recover was possible ending to destruction of crop or only few plants were survived.

Weed control rating:

Application of bensulfuron methyl 0.6 G + pretilachlor 6.0 G 6.6 EC at both the dosage at165 g/ha and 330 g/ha and pendimethalin 38.7 CS at 680 and 1000 g/ha gave excellent weed control.

All other herbicides used for screening gave good control of weeds. Atrazine 50 WP in kodo millet though controlled weeds, resulted in destruction of crop.

Weed species:

The important weed flora in kodo millet are in sedges *Cyperus rotundus*, among grasses *Cynodon dactylon*, *Digitaria marginata*, *Dactyloctenium egyptium*; *Echinochloa colona*, *Brachiaria repens* ; *Eleusine indica*, in broad leaf weeds *Ageratum conyzoides*, *Alternanthera sessilis*, *Borreria hispida*, *Commelina benghalensis*, *Phyllanthus niruri*; *Spilanthes acmella Oldenlandia corymbose, Mimosa pudica*; *Sida acuta*, *Acanthospermum hispidium*; *Cleome viscosa Amaranthus viridis*; *Legascea mollis*.

Weed Density (g/m^2):

Pre-emergence herbicides application of bensulfuron methyl 0.6 G + pretilachlor 6.0 G 6.6 EC at both the dosage at 165 g/ha and 330 g/ha recorded lower weed count in sedges, grasses and broad leaf weeds at 30 60 and at 90 days of crop and pendimethalin 38.7 CS at 680 and 1000 g/ha recorded lower weed count in sedges and grasses which was on par with two hand weeding at 20 and 40 DAS (Table 19).

Weed dry weight (g/m^2):

Weed dry weight as influenced by application of different pre-emergence herbicides in Kodo millet recorded significantly lower sedges, narrow leaf weeds and broad leaf weeds at 30 DAS. Plots treated with herbicides viz., bensulfuron methyl 0.6 G + pretilachlor 6.0 G 6.6 EC at both the dosage at 165 g/ha and 330 g/ha and pendimethalin 38.7 CS at 680 and 1000 g/ha recorded significantly lower total weed dry weight 7.82, 2.94, 5.59, 3.74 g/m2 respectively compared to weedy check (11.2 g/m2). Higher dosage of herbicide were effective than the lower dosage of herbicides.

Grain Yield:

Grain yield was found significant in all treatments except butachlor and atrazine, indicating that the few pre-emergent herbicides used for screening for kodo millet had adverse effect on yield of grain. Highest seed yield was recorded in Hand weeding which recorded 2.03 t/ha, which was on par with application bensulfuron methyl 0.6 G + pretilachlor 6.0 G at both the dosage at 165 g/ha and 330 g/ha and pendimethalin 38.7 CS at 680 and 1000 g/ha.

The other pre-emergent herbicides recorded lower straw yield either due to phytotoxicity at early stage of crop or poor stand of crop.

Recommendation:

From the preliminary screening of the pre-emergence herbicides in kodo millet, for the two years 2019-20 and 2020-21, It was observed pre-emergence application of bensulfuron methyl 0.6 G + pretilachlor 6.0 G 6.6 EC at both the dosage 165 g/ha and 330 g/ha and pendimethalin 38.7 CS at 680 and 1000 g/ha can be recommended for controlling weeds effectively in kodo millet as pre-emergent.

Table 18. Crop Toxicity Ratings as influenced by different pre- emergent herbicides in irrigated Kodo Millet sown during *Kharif* 2020 at Main Research Station, Hebbal, Bangalore.

Pre-emergence Treatments	Dose g/ha	Crop Toxicity Rating (DAS)*										
		0	1	3	5	7	10	15	18	20	25	30
Oxadiargyl 80 WP	50	0	0	0	0	1	1	1	0	0	0	0
Oxadiargyl 80 WP	75	0	0	0	0	1	1	1	0	0	0	0
Bensulfuron methyl 0.6 G + pretilachlor 6.0 G	165	0	0	0	0	0	0	0	0	0	0	0
Bensulfuron methyl 0.6 G + pretilachlor 6.0 G	330	0	0	0	0	0	0	0	0	0	0	0
Butachlor 50 EC	750	0	0	0	1	1	0	0	0	0	0	0
Butachlor 50 EC	1000	0	0	0	1	1	0	0	0	0	0	0
Pendimethalin 38.7 CS	680	0	0	0	0	0	0	0	0	0	0	0
Pendimethalin 38.7 CS	1000	0	0	0	0	0	0	0	0	0	0	0
Atrazine 50 WP	250	0	0	0	0	0	1	1	1	1	1	1
Atrazine 50 WP	500	0	0	0	0	1	1	1	1	1	1	1
Two Hand weeding (20 & 40 DAS)	NA	0	0	0	0	0	0	0	0	0	0	1
Weedy Check	NA	0	0	0	0	0	0	0	0	0	0	0

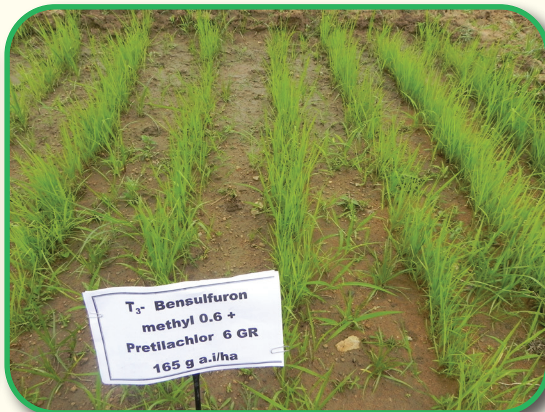
* 0-No injury, Normal; 1- Injury; 10 – complete destruction * DAS- Days after sowing, NA: Not applicable

Table 19. Weed control ratings as influenced by different pre emergent herbicides in irrigated Kodo Millet sown during *Kharif* 2020 at Main Research Station, Hebbal, Bangalore.

Pre-emergence Treatments	Dose g/ha	Formulation (g/ha)	Weed Control Rating (DAS)*										
			0	1	3	5	7	10	15	18	20	25	30
Oxadiargyl 80 WP	50	63	7	7	7	7	7	8	8	8	8	8	8
Oxadiargyl 80 WP	75	94	7	7	7	7	7	8	8	8	8	8	8
Bensulfuron Methyl 0.6 G + pretilachlor 6.0 G	165	2500	8	8	8	9	9	9	9	9	9	9	9
Bensulfuron methyl 0.6 G + pretilachlor 6.0 G	330	5000	8	8	8	9	9	9	9	9	9	9	9
Butachlor 50 EC	750	1500	7	7	7	7	7	8	8	8	8	8	8

Pre-emergence Treatments	Dose g/ha	Formulation (g/ha)	Weed Control Rating (DAS)*										
			0	1	3	5	7	10	15	18	20	25	30
Butachlor 50 EC	1000	2000	7	7	7	7	7	8	8	8	8	8	8
Pendimethalin 38.7 CS	680	1757	8	8	8	9	9	9	9	9	9	9	9
Pendimethalin 38.7 CS	1000	2584	8	8	8	9	9	9	9	9	9	9	9
Atrazine 50 WP	250	500	7	7	7	7	7	6	6	6	6	6	6
Atrazine 50 WP	500	1000	7	7	7	7	7	6	6	6	6	6	6
Two Hand weeding	NA	20 & 40 DAS	Not applicable										
Weedy Check	NA	NA											

Bensulfuron methyl 0.6 G + pretilachlor 6.0 G 330 g /ha



Bensulfuron methyl 0.6 G + pretilachlor 6.0 G 165 g /ha

Pendimethalin 38.7 EC 680 g/ha

Pendimethalin 38.7 EC 1000 g/ha

Effect of pre-emergent herbicides in kodo millet

Evaluation of post-emergence herbicide in kodo millet

Weed species:

The major weed species found were, among sedges, *Cyperus rotundus* in grasses *Cynodon dactylon*, *Digitaria marginata*, *Brachiaria ramose*, *Dactyloctenium aegyptium*, *Eleusine indica*, *Echinochloa colona*, *Eragostris pilosa*. Among broadleaf weeds *Chloris barbata*, *Borreria hispida*, *Commelina benghalensis*, *Mimosa pudica*, *Oldenlandia corymbosa*, *Phyllanthus niruri*, *Ageratum conyzoides*, *Acanthospermum* *hispida*, *Alternanthera sessilis, Sida acuta*, *Tridax procumbense*; *Euphorbia hirta*, *Amaranthus viridis* and *Spilanthus acmella*.

Post-emergence application of metsulfuron methyl + chlorimuron ethyl 20 WP at 4 g/ha and 2, 4 D sodium salt 80 WP 750 g/ha holds immense potentiality in controlling weeds effectively in kodo millet. Hence, these herbicides can be recommended for controlling weeds effectively in Kodo millet, if applied when the weeds are at 2-4 leaf stage.

2, 4-D sodium salt 80WP 750 g/ha

Metsulfuron + Chlorimuron 20WP (2+2) 4 g/ha

Unweeded check

Post-emergent herbicide in Kodo millet (*Paspalum scrobiculatum* (L.) P. Beauv)

Weed Management in Organically grown *Kharif*- Kodo millet- *Rabi*- Black gram (*Vigna mungo*) cropping system.

Weed Flora: Major weed flora observed in the experimental plots was Sedges- *Cyperus rotundus*; Grasses- *Cynodon dactylon*, *Digitaria marginata*, *Echinochloa colona*, *Dactyloctenium aegyptium*, *Eleusine indica*. In Broad leaf weeds *Borreria hispida*, *Commelina benghalensis*, *Phyllanthus niruri*, *Alternanthera sessili*, *Spilanthus acmella*, *Oldenlandia corymbosa*, *Ageratum conyzoides*, *Amaranthus viridis*, *Cleome viscosa* and *Portulaca oleracea*.

Stale seed bed technique + inter cultivation at 25 DAS and 45 DAS and inter cultivation at 25 DAS + 1 hand weeding at 45 DAS were found to be effective in controlling weeds. Hence under non chemical method of weed control and in a situation where availability of labor is crucial, managing weeds through combination of various cultural operations like stale seed bed technique and inter cultivation practices plays a greater role in controlling weeds at critical period of crop growth.

Hand weeding at 20 & 40 DAS

Two mechanical (Cycle weeder) weeding at 20 and 40 DAS

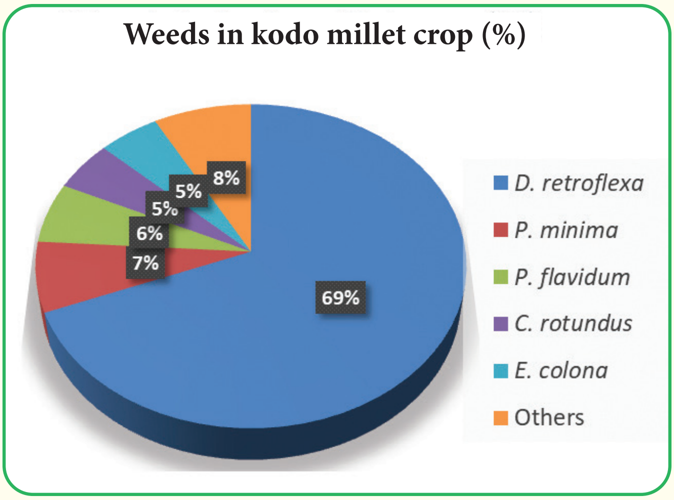
Stale seed bed technique + Intercultivation at 25 DAS & 45 DAS

Intercultivation at 25 DAS + 1 Hand weeding at 45 DAS

Non-chemical methods of weed management in Kodo millet

Madhya Pradesh (ICAR-Directorate of Weed Research, Jabalpur)

Weed management in transplanted kodo millet



Higher WCE was obtained under oxyfluorfen 100 g/ha *fb* 1 HW at 40 DAP (91.2%), metribuzin 150 g/ha *fb* 1 HW at 40 DAP (90.0%), 2 HW (85.3%). Two HW recorded highest grain yield of 3.10 t/ha comparable to oxyfluorfen 100 g/ha *fb* 1 HW, pendimethalin 675 g/ha *fb* metsulfuron 4 g/ha 25 DAP, and metribuzin 150 g/ha *fb* 1 HW at 40 DAP . The unweeded check reduced the grain yield by 51.6%. Higher B:C was recorded under pendimethalin 675 g/ha *fb* 1 HW at 40 DAP (3.72), oxyfluorfen 100 g/ha *fb* 1 HW at 40 DAP (3.64) and pendimethalin 675 g/ha *fb* metsulfuron 4 g/ha 25 DAP (3.57).


Oxyfluorfen 100 g/ha
fb 1 HW
at 40 DAP


2 HW


Unweeded

Foxtail millet

In India, foxtail millet (*Setaria italica* (L.) P. Beauv is mainly grown to some extent in Andhra Pradesh, Karnataka, Tamil Nadu, Madhya Pradesh, Uttar Pradesh, and northeastern states of India. Weeds cause enormous loss of the crop produced every year and no improved system of management was developed to control such weeds as it was a neglected crop. Though hand weeding is most effective, it is always not possible, because of demand and cost of human labour.

Karnataka (UAS, Bengaluru)

Non-chemical weed management in foxtail millet

Millets are usually grown as rain-fed crop in less fertile and marginal lands.

Weed flora: Major weed species observed in foxtail were *Cyperus rotundus* (among sedges) *Digitaria marginata*, *Dactyloctenium aegyptium*, *Echinochloa crusgalli*, *Echinochloa colona*, *Eleusine indica*, *Setaria glauca* (among grasses). Whereas, broad-leaved weeds were *Borreria hispida*, *Boerhavia diffusa*, *Cleome viscosa*, *Spilanthus acmella*, *Sida acuta*, *Oldenlandia corymbosa*, *Ageratum conyzoides*, *Alternanthera sessilis*, *Acanthospermum hispidium*, *Commelina benghalensis*. Grasses dominated the weed flora followed by broad-leaved weeds and sedges Among the weed species, the density of broad-leaved weeds were higher than other weed species, followed by grasses and sedges. Indicating the broad-leaved weed dominance from the beginning of the crop cycle. Crop toxicity rating as influenced by herbicides are mentioned in Table 20 and 21.

Weed density: Weed density and weed dry weight at 30 DAS indicated that, among the weed flora sedges were less in density compared to grasses and broad-leaved weeds. Among different category of weeds, in unweeded control the density and dry weight of broad-leaved weeds (BLW) and grasses were higher than sedges (Table 22).

At 30 DAS, hand weeding at 20 and 40 DAS recorded significantly lower weed density compared to other non-chemical methods of weed control due to complete removal of weeds by employing manual labour. Although it is costly, labour intensive and tedious job.

Among other non-chemical methods, stale seed bed technique followed by inter-cultivation at 25 at 45 DAS, following inter cultivation 25 DAS and one hand weeding at 45 DAS reduced the weeds' density significantly over other treatments, which was comparable to hand weeding at 20 and 40 DAS (Table 20).

Under unweeded control, at 60 DAS the density of broad-leaved weeds (29.8 no./m^2) was highest followed by grasses (23.8 no./m^2) while it was comparatively lower in sedges (17.33 no./m^2). While at harvest the trend was vice versa the density of grasses (31.00 no./m^2) was highest followed by broad-leaved weeds (29.67 no./m^2) and sedges (12.0 no./m^2).

The total weed density was significantly lower in hand weeding at 20 and 40 DAS. While the weed density with stale seed bed technique followed by inter-cultivation at 25 at 45 DAS was on par with inter-cultivation once at 25 DAS *fb* one hand weeding at 45 DAS at 60 DAS and recorded lower total weed density compared to other treatments All weed management treatments recorded significantly lower total weed density at harvest except stale seed bed technique, Bio mulching with coriander and straw mulching which was on par with unweeded control.

Weed dry weight: Among weed control treatment, hand weeding at 20 and 40 days after sowing recorded significantly lower total weed dry weight (g/m^2) at all the stages of observation (30, 60 and at harvest). The best treatment (hand weeding) was on par with Stale seed bed technique + intercultivation twice at 25 & 45 days after sowing followed by Inter cultivation at 25 days after sowing + 1 hand weeding at

45 days after sowing, whereas, Stale seed bed technique alone, Straw mulching and Bio mulching with Coriander and Cowpea were not significant in controlling weeds (Table 23).

At 30, 60 days after sowing and at harvest weed dry weight were significantly lower in hand weeding at 20 and 40 days after sowing (1.63, 2.28 and 2.46 g/m^2) treatment, and was on par with Stale seed bed technique + inter-cultivation twice at 25 & 45 days after sowing (1.83, 2.30 and 2.54 g/m^2) followed by Inter cultivation at 25 days after sowing + 1 hand weeding at 45 days after sowing (1.96, 2.33 and 2.61 g/m^2). While other treatments recorded higher weed dry weight at 30, 60 and at harvest.

Seed yield (Table 24) of foxtail millet was significantly higher in hand weeding at 20 and 40 DAS (1.38 t/ha) as compared to unweeded control. However, it was on par with Stale seed bed technique + inter-cultivation twice at 25 & 45 days after sowing (1.31 t/ha) and followed by Inter cultivation at 25 days after sowing + 1 hand weeding at 45 days after sowing (1.28 t/ha). The highest yield might be due to better control of weeds at (tillering stage) which is critical stage of crop weed competition (Table 24). Whereas lower seed yield (0.58 t/ha) was obtained in unweeded control. This reduction in yield might be due to highest competition with foxtail millet throughout the crop growth period.

Economics: Highest gross return (Rs. 37,436 /ha) was obtained in hand weeding 20 and 40 days after sowing followed by Inter cultivation at 25 days after sowing + 1 hand weeding at 45 days after sowing (Rs. 34,760/ha); Stale seed bed technique + inter-cultivation twice at 25 & 45 days after sowing (Rs. 35,556 /ha). While, the highest net return was obtained in stale seed bed technique + inter-cultivation twice at 25 & 45 days after sowing (Rs. 19,874 /ha) followed by inter-cultivation at 25 days after sowing + 1 hand weeding at 45 days after sowing (Rs.19,542/ha) followed by Whereas, the BC ratio was higher in Inter cultivation at 25 days after sowing + 1 hand weeding at 45 days after sowing (2.28) due to lower cost of cultivation than Hand weeding at 20 and 40 days after sowing (2.03). Hand weeding twice at 20 and 45 days after sowing did produce higher gross return, but net return and BC ratio was lower because of availability of labour at crucial stage besides, the labour demands higher wages increased higher cost of cultivation thus results in lower BC ratio.

Recommendation: Hand weeding twice at 20 and 40 days after sowing is the best non-chemical method of weed control which produces significantly highest yield. The labour availability is a problem, besides high cost involved in hand weeding resulted in lower BC ratio and net returns. Stale seed bed technique + inter-cultivation twice at 25 & 45 days after sowing and inter-cultivation at 25 days after sowing + 1 hand weeding at 45 days after sowing could be viable alternative for weed management in non-chemical method of foxtail millet cultivation.

Inter-cultivation at 25 DAS + One Hand Weeding at 45 DAS

Stale Seed Bed Technique + Inter-cultivation at 45 DAS

Straw Mulching 5 t/ha at 10-15 DAS **Unweeded Control**

Non-chemical methods of weed management in foxtail millet

Post-emergent herbicide in foxtail millet

Though manual weeding is the most common method of weed control but in many instances the available labour is unable to weed vast areas of land during the critical periods, this makes the application of herbicides very important. No post emergent herbicides were evaluated in the foxtail millet earlier. Therefore, a study was undertaken to evaluate the post-emergent herbicides.

Application of metsulfuron methyl +chlorimuron ethyl 20 WP 4 g/ha gave good control of weeds followed by bispyribac sodium 10 EC 20 g/ha, 2 4 D sodium salt 80 WP 1000 g/ha, ethoxysulfuron 15 WG 15.0 g/ha. While other herbicides gave moderate to satisfactory control of weeds (Table 19).

Crop Phytotoxicity: In the first year of the experiment, none of the herbicide showed any phytotoxicity on the crop. In second year, application of bispyribac sodium 10 EC 15 and 20 g/ha and ethoxysulfuron 15 WG 15.0 g/ha initially showed slight leaf tip scorching (Table 20), later regained after 17 DAHA (days after herbicide application) and delay in growth over non-herbicide application was noticed. Later, crop recovered as the new growth was noticed.

Weed flora: The general weed flora of the experimental field during the cropping period primarily composed of grasses, sedge and broad-leaved weeds. The major weed species found in relative with the crops are, Sedges- *Cyperus rotundus*; among Grasses-*Cynodon dactylon*; *Digitaria marginata, Echinochloa colona; Dactyloctenium aegyptium; Eelusine indica; In* Broad-leaved weeds *Achyranthes aspera, Amaranthus viridis, Acanthospermum hispida, Ageratum conyzoides, Alternanthera sessilis, Borreria hispida, Commelina benghalensis, Cinebra didema, Catharanthus pusillus, Celosia argentea Cleome viscosa; Euphorbia hirta, Oldenlandia corymbosa, Phyllanthus niruri, Spilanthus acmella; Sida acuta, Vinca puscilla.*

Weed Density and weed dry weight: Weed control treatments hysterically altered the density of weed species over weedy check. Considerable reduction in weed flora was observed, significant reduction of the weed population was found and controlled complex weed flora and reduced the density of weeds. Obviously unweeded control resulted in higher density of grasses, sedge and broad-leaved weeds due to unmanaged and increased weed growth at all the growth at all the crop growth stages. The same trend was followed in weed dry weight (g/m^2) (Table 22).

Recommendation: In Foxtail millet, the post-emergence herbicides-metsulfuron methyl + chlorimuron ethyl WP-20 WP (2+2) 4 g/ha and 2, 4 D sodium salt 80 WP 1000 g/ha were found to be a promising herbicide in controlling complex weed flora. By considering the present-day situation where hand weeding is a time consuming and costly method, these herbicides have been found to be effective, if sprayed at 2-4 leaf stage.

Table 20. Crop toxicity ratings as influenced by different post emergent herbicides in foxtail sown during *Kharif* 2020-21 at Main Research Station, Hebbal, Bangalore.

Post Emergence Treatments	Dose g/ha	Formulation (g/ha)	Crop Toxicity Rating (DAHS)*										
			0	1	3	5	7	10	15	18	20	25	30
Bispyribac sodium 10 EC	15	150	0	0	0	0	0	0	0	0	0	0	0
Bispyribac sodium 10 EC	20	200	0	0	0	0	0	0	0	0	0	0	0
Metsulfuron + chlorimuron 20 WP (2+2)	3	15	0	0	0	0	0	0	0	0	0	0	0
Metsulfuron + chlorimuron 20 WP (2+2)	4	20	0	0	0	0	0	0	0	0	0	0	0
2, 4-D sodium salt 80WP	1000	1250	0	0	0	0	0	0	0	0	0	0	0
2, 4-D sodium salt 80WP	500	625	0	0	0	0	0	0	0	0	0	0	0
Ethoxysulfuron 15 WG	10	67	0	0	0	0	0	0	0	0	0	0	0
Ethoxysulfuron 15 WG	15	100	0	0	0	0	0	0	0	0	0	0	0
Two hand weeding at 20 & 40 DAS	--		0	0	0	0	0	0	0	0	0	0	0
Mechanical weeding by cycle weeder at 20 and 40 DAS	-		0	0	0	0	0	0	0	0	0	0	0
Un weeded check			0	0	0	0	0	0	0	0	0	0	0

*DAHS- Days after Herbicide spray 0-No injury, Normal; 1- Injury; 10 – complete destruction

Table 21. Crop toxicity ratings as influenced by different post emergent herbicides in irrigated foxtail during *Kharif* 2021-22 at GKVK.

Post Emergence Treatments	Dose g /ha	Formulation (g/ha)	Crop Toxicity Rating (DAHS)*										
			0	1	3	5	7	10	15	18	20	25	30
Bispyribac sodium 10 EC	15	150	0	0	1	1	1	1	0	0	0	0	0
Bispyribac sodium 10 EC	20	200	0	0	1	1	1	1	0	0	0	0	0
Metsulfuron + chlorimuron 20 WP (2+2)	3	15	0	0	0	0	0	0	0	0	0	0	0
Metsulfuron + chlorimuron 20 WP (2+2)	4	20	0	0	0	0	0	0	0	0	0	0	0
2, 4-D sodium salt 80WP	1000	1250	0	0	0	0	0	0	0	0	0	0	0
2, 4-D sodium salt 80WP	500	625	0	0	0	0	0	0	0	0	0	0	0
Ethoxysulfuron 15 WG	10	67	0	0	0	0	0	0	0	0	0	0	0
Ethoxysulfuron 15 WG	15	100	0	0	1	1	1	1	0	0	0	0	0
Two hand weeding at 20 & 40 DAS	--	-	0	0	0	0	0	0	0	0	0	0	0
Mechanical weeding by cycle weeder at 20 and 40 DAS	-	-	0	0	0	0	0	0	0	0	0	0	0
Un weeded check			0	0	0	0	0	0	0	0	0	0	0

*DAHS- Days after Herbicide spray 0-No injury, Normal; 1- Injury; 10 – complete destruction

Table 22. Effect of different post-emergent herbicides on weed density (No./m²) at 30 Days after sowing in foxtail millet (pooled data 2020-22).

Post Emergence Treatments	Dose g/ha	Formulation (g/ha)	Sedge	Grass	Broad-leaved	Total
Bispyribac sodium 10 EC	15	150	3.15 (10.00)	3.80 (14.00)	6.20 (38.00)	7.90 (62.00)
Bispyribac sodium 10 EC	20	200	3.20 (10.33)	4.48 (19.67)	5.55 (30.33)	7.79 (60.33)
Metsulfuron + chlorimuron 20 WP (2+2)	3	15	3.04 (11.67)	4.24 (17.67)	6.26 (39.00)	8.28 (68.33)
Metsulfuron + chlorimuron 20 WP (2+2)	4	20	2.58 (8.00)	4.30 (18.00)	5.04 (25.33)	7.18 (51.33)
2, 4-D sodium salt 80WP	1000	1250	3.80 (14.33)	4.02 (16.00)	5.25 (27.33)	7.61 (57.67)
2, 4-D sodium salt 80WP	500	625	2.50 (7.67)	3.39 (11.33)	6.00 (35.67)	7.39 (54.67)
Ethoxysulfuron 15 WG	10	67	2.38 (6.00)	4.73 (22.00)	6.36 (40.00	8.27 (68.00)
Ethoxysulfuron 15 WG	15	100	2.77 (9.33)	3.66 (13.00)	5.79 (33.00)	7.46 (55.33)
Two hand weeding at 20 & 40 DAS	-	-	2.47 (6.00)	2.24 (4.67)	3.07 (9.00)	4.47 (19.67)
Mechanical weeding by cycle weeder at 20 and 40 DAS	-	-	3.02 (8.67)	3.34 (10.67)	3.57 (12.33)	5.67 (31.67)
Un weeded check	-	-	3.16 (10.00)	5.27 (27.33)	7.94 (62.67)	10.02 (100.00)
SEm ±	-	-	0.78	0.24	0.28	0.29
LSD (0.05)	-	-	NS	0.71	0.82	0.87

(Figures in parentheses indicate original values; Data were subjected to square-root transformation before statistical analysis- ($\sqrt{x+0.5}$),

Table 23. Effect of different post-emergent herbicides on weed dry weight (g/m²) at 30 Days after sowing in foxtail millet (pooled data 2020-22).

Post Emergence Treatments	Dose (g/ha)	Formulation (g/ha)	Sedge	Grass	Broad-leaved	Total
Bispyribac sodium 10 EC	15	150	1.06 (0.63)	1.88 (3.03)	1.81 (2.82)	2.64 (6.48)
Bispyribac sodium 10 EC	20	200	1.13 (0.78)	1.46 (1.68)	1.66 (2.33)	2.30 (4.79)
Metsulfuron + chlorimuron 20 WP (2+2)	3	15	0.94 (0.42)	1.91 (3.18)	1.81 (2.78)	2.62 (6.38)
Metsulfuron + chlorimuron 20 WP (2+2)	4	20	0.88 (0.31)	1.42 (1.52)	1.71 (2.43)	2.18 (4.25)

Post Emergence Treatments	Dose (g/ha)	Formulation (g/ha)	Sedge	Grass	Broad-leaved	Total
2, 4-D sodium salt 80WP	1000	1250	1.12 (0.76)	1.68 (2.34)	1.71 (2.44)	2.46 (5.54)
2, 4-D sodium salt 80WP	500	625	1.29 (1.16)	1.75 (2.57)	2.15 (4.20)	2.90 (7.93)
Ethoxysulfuron 15 WG	10	67	1.11 (0.73)	1.71 (2.45)	1.67 (2.31)	2.44 (5.49)
Ethoxysulfuron 15 WG	15	100	0.96 (0.46)	1.52 (1.84)	1.73 (2.51)	2.29 (4.81)
Two hand weeding at 20 & 40 DAS	-	-	0.97 (0.46)	1.28 (1.16)	1.55 (1.90)	2.00 (3.51)
Mechanical weeding by cycle weeder at 20 and 40 DAS	-	-	0.96 (0.44)	1.25 (1.07)	1.57 (1.97)	1.99 (3.48)
Un weeded check	-	-	1.20 (1.15)	1.71 (2.43)	1.89 (3.15)	2.68 (6.73)
SEm ±	-	-	0.13	0.08	0.11	0.10
LSD (0.05)	-	-	NS	0.25	NS	0.30

(Figures in parentheses indicate original values; Data were subjected to square-root transformation before statistical analysis- ($\sqrt{x}$ +0.5),

Table 24. Grain yield and economics as influenced by different post-emergent herbicides on foxtail millet (pooled analysis 2020-22).

Post Emergence Treatment	Dose g /ha	Formulation (g/ha)	Seed Yield (t/ha)	WI (%)	Gross returns Rs/ha	Net returns (Rs/ha)	B:C	Marginal returns (Rs/ha) over unweeded control	Savings in weeding cost Rs/ha
Bispyribac sodium 10 EC	15	150	0.41	53.90	14490	4880	1.51	2713	5090
Bispyribac sodium 10 EC	20	200	0.67	25.95	23275	13195	2.31	11498	4620
Metsulfuron + chlorimuron 20 WP (2+2)	3	15	0.46	48.78	16100	7513	1.87	4323	6113
Metsulfuron + chlorimuron 20 WP (2+2)	4	20	0.82	9.24	28525	19809	3.27	16748	5984
2 4 D sodium salt 80WP	1000	1250	0.86	3.90	30205	21503	3.47	18428	5998
2 4 D sodium salt 80WP	500	625	0.45	50.11	15680	7229	1.86	3903	6249
Ethoxysulfuron 15 WG	10	67	0.48	46.38	16853	8279	1.97	5075	6127
Ethoxysulfuron 15 WG	15	100	0.54	39.70	18953	10193	2.16	7175	5940
Two hand weeding at 20 & 40 DAS	-	-	0.90	0.00	31430	16730	12.14	19653	0

Post Emergence Treatment	Dose g /ha	Formulation (g/ha)	Seed Yield (t/ha)	WI (%)	Gross returns Rs/ha	Net returns (Rs/ha)	B:C	Marginal returns (Rs/ha) over unweeded control	Savings in weeding cost Rs/ha
Mechanical weeding by cycle weeder at 20 and 40 DAS	-	-	0.84	6.29	29453	17641	2.49	17675	488
Un weeded check	-	-	0.34	62.50	11778	177	1.02	0	6500
SEm ±	-	-	0.03	NA					
LSD (0.05)	-	-	0.08						

Little millet

Metsulfuron + chlorimuron 20 WP (2+2) 4 g/ha

2,4-D sodium salt 80 WP 1000 g/ha

Two hand weeding at 20 & 40 DAS

Un weeded check

Post- emergent herbicides in foxtail millet

Karnataka (UAS, Bengaluru)

Among the minor millets, little millet (*Panicum sumatrense* Roth ex Roem. & Schult. subsp. sumatrense) is amazing in their nutrient content and nutritionally superior to other cereals like rice and wheat. The initial growth of millets is very slow, which paves favourable conditions for weed multiplication and wide spectrum of weed flora to occur. Thus, crop that suffers heavy weed infestation, gradually become a serious limitation for low production, hence effective control of weeds at critical crop growth period is vital.

Screening of herbicides for little millet

The screening of herbicides was conducted in two phases

Phase I: Screening of herbicides for little millet

Phase II: Screening of herbicides for little millet with 50 % reduced dose of screened herbicides under phase I

Weed flora: Major weed flora observed in experimental plots during investigation were, *Echinochloa colona*, *Echinochloa crusgalli*, *Dactyloctenium aegyptium*, *Setaria glauca*, *Brachiaria reptans*, *Echinochloa indica*, *Chloris barbata* and *Cynodon dactylon* among grasses; *Cyperus rotundus* among sedges, Whereas, broad-leaved weeds were *Borreria hispida*, *Spilanhus acella*, *Ageraum coyzoides*, *Acanthospermum hispidium* and *Commelina benghalensis*.

Pre-emergent application of different herbicides at different doses had phytotoxic effect on little millet. All the pre-emergent herbicide plots showed complete destruction of crop stand (Table 25). All the herbicides tested at the respective dosage in little millet proved effective in controlling weeds. On the basis of the results obtained under phase I, treatments were revised to 50% lower of the tested dose. Pre-emergence herbicides application at re4duced doses gave excellent to good control of weeds at 30 DAS, which was comparable to inter-cultivation and hand weeding at 20 and 40 DAS. Un-weeded check recorded highest weed density. Application of herbicides no doubt gave excellent weed control and was also significant over weedy check, due to its phytotoxicity on the crop and complete inhibition of germination, the herbicide is not considered for recommendation.

Table 25. Crop Toxicity Ratings as influenced by different herbicides in little millet under

The herbicide applied plots of little millet both at tested dosage and the 50 % of tested level of application of herbicide caused phytotoxic and completely inhibited the germination.

(Phase I).

Treatments	Days after herbicide application (DAHA)							
	3	5	7	15	18	20	25	30
PE- Pendimethalin 1.0 kg/ha *fb* Intercultivation at 30 DAS	10	10	10	10	10	10	10	10
PE- Oxyfluorfen 0.5 kg/ha *fb* Intercultivation at 30 DAS	10	10	10	10	10	10	10	10
PE- Oxadiargyl 70 g /ha *fb* Intercultivation at 30 DAS	2	2	2	7	10	10	10	10
PE- Bensulfuron + pretilachlor 660 g/ha (RM) *fb* Intercultivation at 30 DAS	2	2	2	7	10	10	10	10
PE- Pendimethalin 1.0 kg/ha *fb* POE 2,4-D Na salt 0.5 kg/ha	10	10	10	10	10	10	10	10
PE- Pendimethalin 1.0 kg/ha *fb* POE byspyribac Na 100ml/ha	10	10	10	10	10	10	10	10
PE Oxyfluorfen 0.5 kg/ha *fb* POE 2,4-D Na salt 0.5 kg/ha	10	10	10	10	10	10	10	10
PE- Oxyfluorfen 0.5 kg/ha *fb* POE byspyribac Na- 100ml/ha	10	10	10	10	10	10	10	10
PE Oxadiargyl 70 g /ha *fb* POE 2,4-D Na salt 0.5 kg/ha	2	2	2	7	10	10	10	10
PE -Oxadiargyl 70 g /ha *fb* POE byspyribac Na- 100ml/ha	2	2	2	7	10	10	10	10
PE -Bensulfuron + pretilachlor 660 g/ha (RM) + POE 2,4-D Na salt 0.5 kg/ha	2	2	2	7	10	10	10	10
Inter cultivation twice at 20 & 40 DAS	0	0	0	0	0	0	0	0
Hand weeding at 20 &40 DAS	0	0	0	0	0	0	0	0
Unweeded control	0	0	0	0	0	0	0	0

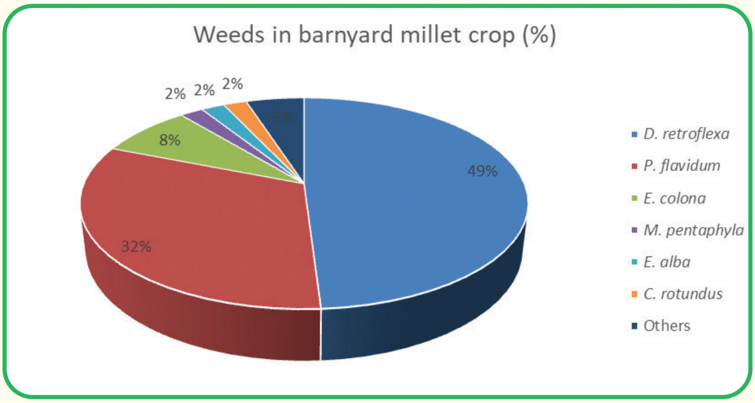
0 - No destruction of crop; 10 - complete destruction of crop

Barnyard millet

In India, barnyard millet (*Echinochloa frumentacea* Link) is mainly grown in Uttarakhand, Uttar Pradesh, Karnataka, Tamil Nadu, Andhra Pradesh, Bihar, Gujarat, Chhattisgarh, and Madhya Pradesh. Due to its remarkable ability to withstand erratic rainfall and varying weather conditions, it has been known as one of the drought stress tolerant hardy crops which are largely cultivated in harsh and fragile environments with minimal use of agricultural inputs. Due to its nutritional quality traits like high dietary fiber content and rich nutritional profile with iron, calcium, magnesium, and zinc minerals, it is gaining importance as a health food.

Madhya Pradesh (ICAR- Directorate of Weed Research, Jabalpur)

Weed management in transplanted barnyard millet



Highest WCE of 90.8 and 90.3% was recorded from 2 HW and oxyfluorfen 100 g/ha *fb* 1 HW. Grain yield of 2.94, 2.85, 2.66 and 2.62 t/ha was recorded under atrazine 750 g/ha *fb* metsulfuron 4 g/ha 25 DAP, 2 HW, oxyfluorfen 100 g/ha *fb* metsulfuron 4 g/ha 25 DAP and oxy *fb* 1 HW, respectively. Higher B:C was recorded under atrazine 750 g/ha *fb* metsulfuron 4 g/ha 25 DAP (2.90), oxyfluorfen 100 g/ha *fb* metsulfuron 4 g/ha 25 DAP (2.64).

Buckwheat

Buckwheat (*Fagopyrum tataricum* and *F. esculentum*) belongs to the family Polygonaceae and it is pseudo-cereal crop. It is commonly grown for its black or gray triangular seeds. It occupies about 70% of the cultivated lands in the higher Himalayas and are grown either as a solid stand or under apple orchards. It is the important staple crop of the mountain regions and is the only crop grown up to 4500 m (Joshi and Paroda 1991).

Himachal Pradesh (CSHPKV, Palampur)

Weed flora: In buckwheat crop in the district Lahul Spiti, *Convolvulus arvensis*, *Dactyloctenium aegyptium* and *Digitaria sanguinalis* occurred frequently (100%) in all samples. But the density, abundance and their relative values were higher in case of *Equisetum typhoides*, *Polygonum alatum* and *Digitaria sanguinalis*. Other weeds observed in the crop were *Gallinsoga parviflora, Daucus carota, Commelina benghalensis, Poa annua, Chenopodium album* and *Malva neglecta.*

During 2005-06 along route-II, buckwheat was invaded by four weed species . Among these *Gallinsoga parviflora* was the most dominating weed with highest density (320 plants/m^2) and relative density of 64.5%. The next dominating weeds were *Digitaria sanguinalis, Polygonum alatum* and *Equisetum* sp. with a density of 100, 60 and 16 plants/m^2, respectively (Table 26).

Table 26. Distribution of different weed species in buckwheat along different routes in Kinnaur district.

Karchham-Katgoan-Kaafnu (route-II)				
Name of weed species	Frequency (%)	Relative frequency(%)	Density (no./m^2)	Relative density (%)
Digitaria sanguinalis	100	25	100	20.2
Polygonum alatum	100	25	60	12.1
Gallinsoga parviflora	100	25	320	64.5
Equisetum sp.	100	25	16	3.2
Karchham-Sangla-Kamru- Changsu (route-III)				
Digitaria sanguinalis	100	22.2	48	29.3
Cyperus sp.	50	11.1	30	18.3
Daucus carota	50	11.1	10	6.1
Commelina benghalensis	50	11.1	6	3.7
Gallinsoga parviflora	100	22.2	62	37.8
Polygonum alatum	50	11.1	6	3.7
Poa annua	50	11.1	2	1.2
Peo-Kalpa-Ribba-Spillo-Pooh-Dabling –Malling- Nako-Chango-Shalkhar (route-IV)				
Convolvulus arvensis	100	25	8	16.7
Digitaria sanguinalis	100	25	20	41.7
Chenopodium album	100	25	8	16.7
Malva neglecta	100	25	12	25.0

On route III, seven weed species invaded the buckwheat crop. *Gallinsoga parviflora* had the highest density 62 plants/m^{-2} and relative density of 37.8 percent. The other dominating weed species were *Digitaria sanguinalis*, *Cyperus* sp. and *Daucus carota* with density of 48, 30 and 10 plants/m^2, respectively.

Along route, Peo-Kalpa-Ribba-Spillo-Pooh-Dabling –Malling- Nako-Chango-Shalkhar, buckwheat was invaded by four weed species. Among these *Digitaria sanguinalis* was the most dominating weed with highest density (20 plants/m^{-2}) and relative density 41.7%. The next dominating weeds were *Malvia neglecta*, *Chenopodium* and *Convolvulus arvensis* with a density of 12, 8 and 8 plants/m^{-2}, respectively.

Weed management: To control weeds in buckwheat, one weeding and hoeing at 20-25 days after seeding or even later is required. However, manual weeding is tedious, cumbersome, costly and dependent upon availability of labour at the right time. A study was undertaken by Rana *et al* (2003) to develop selective herbicidal weed control in buckwheat.

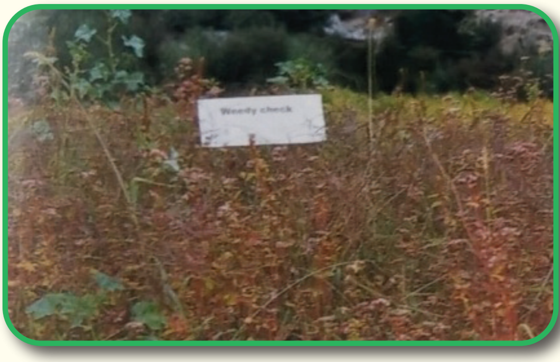
In tartary buckwheat, alachlor 1.50 kg/ha increased seed yield by 57.85 and 20.54%, respectively over hand weeding and by 169.8 and 89.63% over weedy check. Other effective herbicides were alachlor 1.0 kg/ha, pretilachlor 1.0 kg/ha and oxyfluorfen 0.25 kg/ha (Table 27). In common buckwheat, alachlor 1.0 kg/ha and metolachlor 1.0 kg/ha increased seed yield by 12.2 and 7.77%, respectively over hand weeding (Table 27).

Table 27 . Effect of herbicidal treatments on weed dry weight and tartary buckwheat yield.

Treatment	Dose (kg/ha)	Weed dry weight (g/m^2)			Seed yield (t/ha)		
		1999	2000	2001	1999	2000	2001
Weedy		-	571.6	263.4	-	0.82	1.64
Hand weeding		41.7	153.9	22.4	1.2	1.4	2.58
Butachlor	1.0	49.0	504.3	-	1.5	1.0	-
Isoproturon	1.0	55.3	564.8	-	1.49	0.14	-
Atrazine	1.0	65.7	508.2	-	1.3	0.13	-
Pretilachlor	1.0	-	180.8	125.8	-	1.62	1.99
Alachlor	1.0	26.7	120.0	30.9	1.62	1.71	2.90
Pendimethalin	1.0	26.3	235.5	90.4	1.61	1.04	2.41
Alachlor	1.5	-	22.2	15.8	-	2.21	3.11
Pendimethalin	1.5	-	157.1	-	-	0.22	-
Fluchloralin	1.0	44.7	106.8	40.7	1.38	1.79	2.79
Oxyfluorfen	0.25	-	186.9	139.8	-	1.58	1.33
LSD (P=0.05)		20.2	75.2	17.2	0.17	0.18	0.63

Table 28. Effect of weed control treatments on weed dry weight and common buckwheat yield.

Treatment	Dose (kg/ha)	Weed dry weight (g/m^2)		Seed yield (t/ha)	
		1999	**2000**	**1999**	**2000**
Weedy	-	-	307.3	-	0.37
Hand weeding	-	20.6	50.0	0.77	0.75
Butachlor	1.0	70.4	285.4	0.59	0.41
Isoproturon	1.0	82.6	288.1	0.56	0.05
Atrazine	1.0	80.8	262.9	0.25	0.02
Pretilachlor	1.0	40.7	61.9	0.66	0.64
Alachlor	1.0	18.4	17.0	0.76	0.87
Pendimethalin	1.0	35.8	58.9	0.69	0.11
Metolachlor	1.0	32.0	18.7	0.71	0.86
LSD (P=0.05)		16.3	23.8	0.06	0.08



Weedy

Alachlor 1.0 kg/ha

Weed management in common buckwheat

In another study, Rana *et al* (2004) reported that alachlor 1.50 kg/ha, alachlor 0.75 kg/ha + hand weeding, oxyfluorfen 0.10 kg/ha + hand weeding and pretilachlor 0.50 kg/ha + hand weeding gave satisfactory weed control and seed yields of tartary and common buckwheat. *Digitaria sanguinalis* was the most competitive weed species. Alachlor 0.75 kg/ha + hand weeding resulted in minimum weed index (-12.0) in tartary buckwheat and alachlor 1.50 kg/ha in common buckwheat (-41.7). Alachlor at 1.50 kg/ha resulted in maximum marginal benefit cost ratio of 6.72 in Tartary buckwheat and 9.37 in common buckwheat. Seed yields of tartary and common buckwheat were negatively associated with weed count and weed biomass. The economic threshold of weeds at the prevalent price of treatments and crop production varied between 12.6-40.8 weeds per m^2 in Tartary buckwheat and 6.6-37.4 in common buckwheat.

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