Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; 8(2): 614-617
Received: 09-01-2019
Accepted: 13-02-2019

Sangeeta Kujur
Dept. of Agronomy, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Vipin Kumar Singh
Dept. of Agronomy, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Dinesh Kumar Gupta
Dept. of Agronomy, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Saurabh Kumar
Dept. of Agronomy, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Debasis Das
Dept. of Agronomy, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Jagadish Jena
Dept. of Agronomy, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Correspondence
Sangeeta Kujur
Dept. of Agronomy, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Integration of different weed management practices for increasing yield of finger millet (*Eleusine coracana* L. Gaertn)

Sangeeta Kujur, Vipin Kumar Singh, Dinesh Kumar Gupta, Saurabh Kumar, Debasis Das and Jagadish Jena

Abstract
In order to investigate the effect of different herbicidal treatments on finger millet crop, a field experiment was carried out in randomized block design with three replication during 2015 at IGKV, Rajmohini Devi College of Agricultural and Research Station, Ambikapur (C.G). Weeds, viz. *Panicum maxima, Elusine indica, Cyperus spp., Cynodon dactylon, Celosia argentea, Alternanthera sessilis, Alternanthera triandra* and *Ageratum conyzoides* were the dominant weeds of the experimental field. Results revealed that number of tillers, LAI, dry matter accumulation, crop growth rate per plant, weed control efficiency, herbicide use efficiency and grain yield were significantly higher under hoeing twice by wheel hoe between rows and intra-row manual weeding at 20 and 40 and hand weeding twice at 20 and 40 DAS.

Keywords: weed dynamics, plant growth, yield

Introduction
Finger millet (*Eleusine coracana* L.) is an important rainfed crop grown in India. It is commonly known as *ragi or madua*. In India, it is cultivated in an area of 1.02 million ha with a production of 1.39 million tonne. In Chhattisgarh, it covers an area of 6.30 thousand ha with a production of 1.50 thousand tonne at an average productivity of 238 kg ha^{-1} (Anonymous, 2017) [1].

In India, to manage food security and malnutrition, dietary diversification must be followed; otherwise biofortification of staple food grains or consumption of nutri-cereals or millets may be adapted (Jena *et al*, 2018) [4]. The grain of finger millet is high in amino acid, lacking in the diets of the poor who live on starchy foods. It is also a rich source of Calcium, Iron, Protein, dietary fiber and other minerals which are recognized for its health beneficial effects. Apart from human consumption, straw is also used as fodder for cattle and green straw is suitable for making silage.

Weed infestation is one of the serious constraints in *ragi* production due to slower initial growth. This situation causes higher competition and may result in drastic reduction in grain yield. Uncontrolled weed growth during crop growth period reduced the grain yield ranging from 34 to 61% (Ramachandra Prasad *et al*., 1991) [8]. Hence, present study was conducted to know the effect of weed management practices on growth and yield in finger millet.

Material and Methods
The experiment was conducted at I.G.K.V., Rajmohini Devi College of Agricultural and Research Station, Ambikapur during *kharif* season 2015. The experiment was laid out in randomized block design with ten treatments replicated thrice. The treatments comprised of different weed management practices viz., T_1:Weedy check (control), T_2 : Hand weeding twice at 20 and 40 DAS, T_3 : Hoeing twice by wheel hoe between rows and intra-row manual weeding at 20 and 40 DAS, T_4 : Isoproturon @ 0.5 kg ha^{-1} pre emergence, T_5 : 2,4-D Na salt @ 0.5 kg ha^{-1} post emergence, T_6 : Isoproturon pre emergence @ 0.5+ 2,4-D Na salt @ 0.5 kg ha^{-1} post emergence, T_7 : Oxyflourfen @ 0.075 kg ha^{-1} pre emergence, T_8: Oxyfluorfen @ 0.075 kg ha^{-1} pre emergence+ 1 HW at 40 DAS, T_9 : Oxadiargyl @ 0.05 kg ha^{-1} pre emergence, T_{10} : Oxadiargyl @ 0.05 kg ha^{-1} pre emergemce + 1 HW at 40 DAS. The soil of experimental field was sandy loam with pH 5.82, medium in available N (226 kg ha^{-1}) and P (10 kg ha^{-1}) and high in available K (288 kg ha^{-1}), respectively. Finger millet variety 'Indira Ragi 1' was sown in July 20, and harvested on November 29, 2015. Weed management practices were adopted as per the treatments.

Total weed population and species wise and their dry weight were recorded randomly under each treatment plot with the help of quadrate. Weed growth rate (WGR) and weed control efficiency (WCE) was also calculated on the basis of dry matter production of weeds. The experimental data recorded for growth, yield attributes and yield of finger millet were statistically analyzed. Data on weed density and dry weight of weeds were transformed using square root transformation ($\sqrt{X+0.5}$) before statistical analysis to normalize their distribution.

Results and Discussion

Effect of crop

Plant height (cm)

The height is an important criterion for judging the growth of *ragi* plant. Data on plant height are recorded at 30, 60, 90 DAS and at harvest. All weed management practices significantly influence the plant height. The highest value of plant height was recorded under treatment hoeing twice by wheel hoe between rows and intra row manual weeding. However, it was found comparable with treatment hand weeding at 20 and 40 DAS. This was obviously due to the reduction in the crop weed competition attributed reduced weed population. Similar trend also reported by Pradhan *et al.* (2010) [7].

Number of tillers plant^{-1}

The maximum number of tillers plant^{-1} was recorded under hoeing twice by wheel hoe between rows and intra row manual weeding which was at par with hand weeding at 20 and 40 DAS, and isoproturon + 2,4-D Na salt @ 0.5 kg ha^{-1} at all the stages *i.e.* 60, 90 DAS and at harvest. This may be due to lower weed density and weed biomass caused low crop-weed competition and thus the crop plant fully utilized nutrients, moisture, space and light hence, might be produced more tillers. Similar finding has also by reported by Pradhan *et al.* (2010) [7].

Leaf area index (LAI)

Vegetative growth of crop, as measured by leaf area index is somehow correlated with radiation load and photosynthetic efficiency of plant. The LAI was significantly influenced by different treatments over control. The highest LAI at 60 DAS was recorded in hoeing twice by wheel hoe between row and intra row manual weeding which was at par with hand weeding 20 and 40 DAS. Kumara *et al.* (2007) [5] has also reported higher leaf area index under weed management treatments and highest under two hand weeding over unweeded control.

Plant dry weight (g plant^{-1})

The maximum dry matter accumulation was accrued in hoeing twice by wheel hoe between rows and intra row manual weeding and hand weeding twice, which were significantly more than all other treatments. Probably due to effective control of first flush of weed at 20 days and second flush of weeds during 20–40 days led to low competitional stress on crop and thus, the crop plants fully utilized nutrients, moisture, space and light hence produce more dry matter production. Among the other treatments isoproturon @ 0.5 + 2, 4-D Na salt @ 0.5 kg ha^{-1}, isoproturon @ 0.5 kg ha^{-1} alone, oxyfluorfen @ 0.075 kg ha^{-1} + 1HW and oxadiargyl @0.05 kg ha^{-1} + 1HW helped to produce maximum plant dry weight per plant (table 1).

Crop growth rate (g day^{-1} plant^{-1}) and relative growth rate (g g^{-1} day^{-1} plant^{-1})

Crop growth rate (g day^{-1}plant^{-1}) and relative crop growth rate (g g^{-1} day^{-1}plant^{-1}) were maximum under all the weed control treatments over weedy check at all the growth stages. Higher crop growth and relative growth rate was recorded in hoeing twice by wheel hoe between rows and intra row manual weeding and hand weeding twice.

Effect of weeds

Weed flora

Major weed flora observed in the experimental plot were *panicum maxima, Elusine indica, Cyperus spp., Cynodon dactylon, Celosia argentea, Alternanthera sessilis, Alternanthera triandra, Ageratum conyzoides* and others were *Melilotus indica, Fimbristylis miliacea, Echinochloa crusgalli, Phylanthus niruri, Commelina benghalensis, Hibiscus micranthus, Digitaria sanguinalis.*

Total weed density (no. m^{-2}) and Dry weight (g m^{-2})

The lowest weed density and dry weight was recorded with hoeing twice by wheel hoe between rows and intra-row manual weeding and hand weeding twice at 20 and 40 DAS. It is mainly due to complete removal of weeds. Among the herbicides, application of isoproturon + 2, 4-D Na salt recorded minimum weed density and dry matter. The highest density and dry weight of weeds was registered under weedy check.

Weed growth rate (g day^{-1} m^{-2})

Weed growth rate showed differential response due to different weed management treatment at various time intervals. Lowest weed growth rate (WGR) was observed under mechanical weeding at 20 and 40 DAS and hand weeding twice at 20 and 40 DAS, because of complete removal of weeds in this treatment. The maximum weed growth rate was recorded under untreated control during all the stages. Mechanical weeding effects can be explained by a low competition of weeds and a high competitiveness of crop. Similar findings were also reported by Pannacci *et al*. (2017) [6] Bàrberi *et al*. (2000) [2] and Dastgheib (2004) [3] in wheat.

Weed control efficiency

Weed control efficiency which indicates the comparative magnitude of reduction in weed dry matter, was highly influenced by different weed control treatments. The WCE was higher with Hoeing twice by wheel hoe between rows and intra-row manual weeding at 20 and 40 and hand weeding twice at 20 and 40 DAS. It is due to lesser weed dry weight of weeds.

Herbicide use efficiency

Herbicide use efficiency at all the stages was maximum under hoeing twice by wheel hoe between rows and intra-row manual weeding and hand weeding twice. Among the herbicidal treatments at 30 DAS it was maximum under isoproturon @ 0.5 + 2, 4-D Na salt @ 0.5 kg ha^{-1} followed by isoproturon@ 0.5 kg ha^{-1}alone. Further at 60, 90 DAS and at harvest, herbicide use efficiency was maximum under oxyfluorfen @ 0.075 kg ha^{-1} + 1HW and oxadiargyl @ 0.05

kg ha^{-1} + 1 HW at 40 DAS. The higher herbicide use efficiency was owing to superior weed control both in terms of reduction in density and biomass of weeds.

Grain yield

All the weed control treatments were significantly superior to weedy check in increasing grain yield. The maximum grain yield was obtained with hoeing twice by wheel hoe between rows and intra-row manual weeding followed by hand weeding at 20 and 40 DAS. Singh *et al*., (2006) [9] also found similar results. Uncontrolled weeds reduced the grain and straw yield of *ragi* by 72 percent, when compare with two hoeing done at 20 and 40 DAS, which was due to high weed density and biomass in weedy check throughout the crop growth period.

Conclusion

Hoeing twice by wheel hoe between rows and intra-row manual weeding is the best efficient method for the weed control which improves plant growth and produces significantly highest grain yield. Among the herbicidal treatments isoproturon @ 0.5 + 2, 4-D Na salt @ 0.5 kg ha^{-1} produce maximum grain yield.

Table 1: Plant population, plant height, days to 50 percent flowering, no of tillers and plant dry weight in finger millet as influenced by different weed management practices.

Treatment	Dose (Kg ha^{-1})	Plant population (m^2)	Plant height (cm)				Days to 50 % flowering	No of tillers $plant^{-1}$			Plant dry weight (g $plant^{-1}$)				LAI
			30 DAS	60 DAS	90 DAS	At harvest		60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	60 DAS
T_1 : Weedy check (control)	-	147.01	44.97	83.87	98.20	93.33	75.33	1.38	1.42	1.42	1.57	6.00	12.21	12.63	1.94
T_2 : Hand weeding twice	-	144.54	52.37	98.20	115.30	112.13	61.67	2.17	3.15	3.15	1.57	10.23	19.03	22.46	3.89
T_3 : Hoeing twice by wheel hoe between rows and intra-row manual weeding	-	145.04	52.47	98.93	116.60	112.43	62.11	2.77	3.20	3.24	1.69	10.34	19.45	22.95	3.90
T_4 : Isoproturon	0.5	145.05	50.83	96.53	114.27	108.10	67.33	1.94	1.78	1.78	1.33	8.75	17.48	18.07	3.69
T_5 : 2,4-D Na salt	0.5	145.53	47.27	86.83	101.53	99.47	74.33	1.67	1.51	1.48	1.69	8.19	14.14	15.76	3.27
T_6 : Isoproturon + 2,4-D Na salt	0.5+0.5	145.05	51.60	97.53	114.63	109.23	64.33	2.11	3.05	3.11	1.48	9.09	18.93	21.46	3.78
T_7 : Oxyfluorfen	0.075	135.17	50.20	93.67	111.63	106.90	72.89	1.72	1.62	1.62	1.39	7.60	14.30	15.02	3.59
T_8 : Oxyfluorfen + 1 HW	0.075	135.67	50.90	97.17	114.60	108.60	66.33	2.02	2.57	2.59	1.31	8.26	15.70	16.35	3.75
T_9 : Oxadiargyl	0.05	135.67	48.40	92.33	109.63	105.60	73.33	1.69	1.51	1.51	1.91	6.93	13.65	14.90	3.53
T_{10} : Oxadiargyl + 1 HW	0.05	135.17	49.73	95.93	112.77	107.60	68.33	1.75	1.81	1.59	1.49	7.77	15.04	15.18	3.66
SEm ±		4.68	1.49	2.88	3.34	3.17		0.23	0.17	0.18	0.14	0.40	1.25	1.53	0.08
CD (P=0.05)		NS	4.43	8.56	9.03	9.13		0.67	0.50	0.53	0.41	1.18	3.71	4.56	0.23

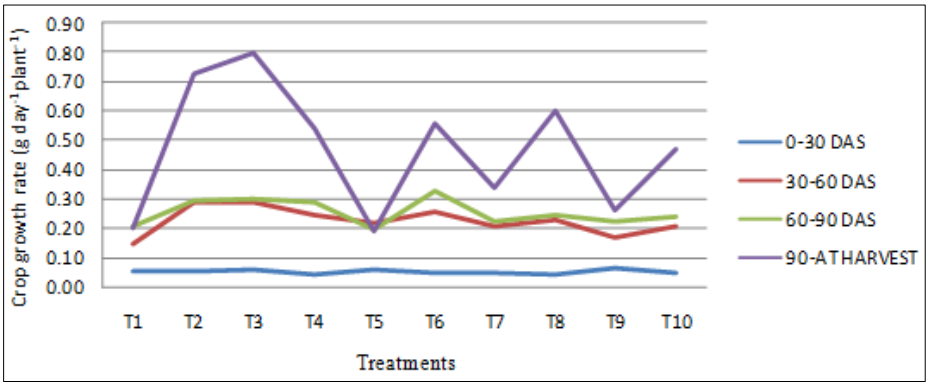

Fig 1: Crop growth rate (g $day^{-1}plant^{-1}$) as affected by weed management practices at various time interval of finger millet.

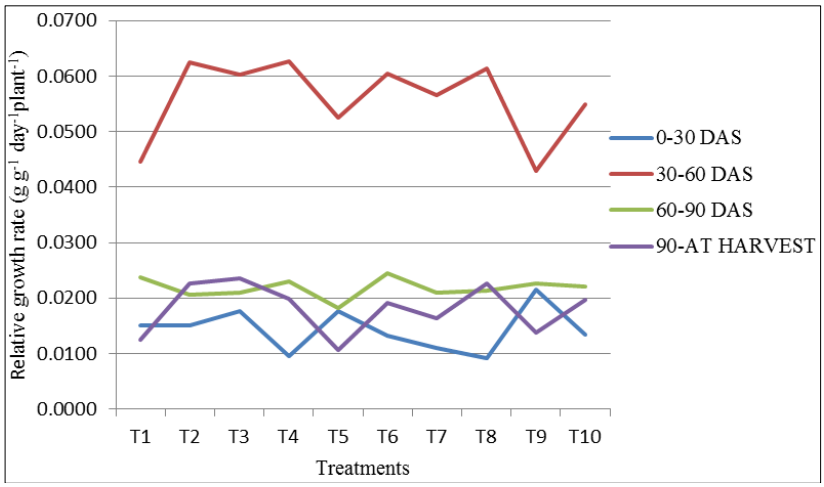

Fig 2: Relative growth rate (g $g^{-1}day^{-1}plant^{-1}$) as affected by weed management practices at various time interval of finger millet.

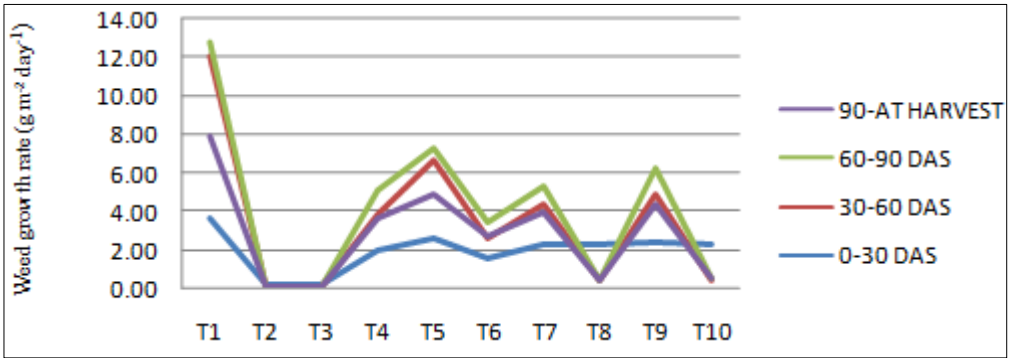

Fig 3: Effect of weed management practices on weed growth rate (g m^{-2} day^{-1})

Table 2: Total weed density, total weed dry weight, weed control efficiency (WCE), Herbicide use efficiency (HUE) and grain yield of finger millet as influenced by different weed management practices

Treatment	Dose (Kg ha^{-1})	Total weed density (no m^{-2}) at 30DAS	Total weed dry weight (g m^{-2}) at 30 DAS	WCE (%) at 30DAS	HUE (%)				Grain yield (q ha^{-1})
					30 DAS	60DAS	90 DAS	At harvest	
T_1 : Weedy check (control)	-	10.52(110.29)	13.03(169.33)	-	-	-	-	-	9.05
T_2 : Hand weeding twice	-	3.10(9.13)	5.99(35.33)	91.72	2.34	6.21	5.52	5.85	29.23
T_3 : Hoeing twice by wheel hoe between rows and intra-row manual weeding	-	2.88(7.80)	5.81(33.33)	92.93	2.64	7.15	6.12	7.19	32.58
T_4 : Isoproturon	0.5	7.87(61.51)	9.44(88.67)	44.23	0.76	1.00	0.89	0.78	20.93
T_5 : 2,4-D Na salt	0.5	8.87(78.29)	11.28(126.67)	29.01	0.23	0.27	0.26	0.24	11.27
T_6 : Isoproturon + 2,4-D Na salt	0.5+0.5	6.91(47.22)	7.86(61.33)	57.19	0.91	1.30	1.15	0.92	22.54
T_7 : Oxyfluorfen	0.075	8.46(71.08)	9.62(92.33)	35.55	0.42	0.56	0.52	0.43	13.67
T_8 : Oxyfluorfen + 1 HW	0.075	8.31(68.84)	9.61(92.00)	37.58	0.73	3.20	2.89	2.05	21.22
T_9 : Oxadiargyl	0.05	8.51(71.98)	10.25(104.67)	34.74	0.37	0.47	0.43	0.38	12.97
T_{10} :Oxadiargyl + 1 HW	0.05	8.43(70.82)	10.21(103.67)	35.79	0.68	2.86	2.59	1.85	19.80
		0.21(0.63)	0.22 0.64						0.61(1.82)

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