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Pre emergence herbicide application and hand weeding for effective weed management in irrigated kodo millet (*Paspalum scrobiculatum* L.)

G Vinothini and P Murali Arthanari

Abstract
Field experiment was conducted at Tamil Nadu Agricultural University, Coimbatore during *kharif* 2014 to evolve weed management through herbicide and hand weeding for higher productivity in kodo millet. The experiment was laid out in randomized block design with three replications. The treatments comprised of different herbicides (pendimethalin, isoproturon and bensulfuron + pretilachlor) with or without hand weeding and mechanical weeder weeding. Pre emergence application of isoproturon 750g/ha followed by hand weeding on 40 days after sowing can keep the weed density and dry weight below the economic threshold level and increase the weed control efficiency under irrigated kodomillet without any phytotoxicity to the crop.

Keywords: supercritical fluid extraction, applications, industry, dairy

1. Introduction
India is the largest producer of many kinds of millets, which are often referred as coarse cereals. Millets are classified into two groups namely major millets and minor millets. The most important minor millets cultivated in India are: Finger millet, Proso millet, Barnyard millet, Italian millet, Kodo millet, Little millet. Among the small millets, Kodo millet (varagu) is amazing in their nutrient content and nutritionally superior to rice and wheat in terms of higher protein, dietary fiber and lesser fat content, which play an important role in the energy requirement and nutrient intake of human. Kodo millet was domesticated in India almost 3000 years ago. It is found across the old world in humid habitats of tropics and subtropics.

Kodo millet (*Paspalum scrobiculatum* L.) was become important minor millet crop cultivated across the India. Small millets occupies an area of 7.99 lakh ha with the production of 4.52 lakh tones in India during 2011-12. (Status paper on Coarse Cereals, 2014) [1] and kodo millet occupies 3340 ha of area and 4511 tonnes of production in Tamil Nadu (Season and Crop Report 2012-13) [2].

The Kodo grain contains 8.3 % protein, 1.4 % fat, 65.6 % carbohydrates. This grain is recommended as a substitute for rice to patients suffering from diabetics.

This crop requires less water and consumed as Kodo rice. This crop suffers heavy weed infestation under irrigated upland conditions. (Adikant Pradhan and Sonboir, 2009) [3]. Slow initial growth of kodo millet and favourable conditions for weed multiplication and a wide spectrum of heterogeneous weed flora, which gradually become a serious limitation for low production of kodo millet (Prajapathi *et al*., 2007) [4]. Effective control of weeds at critical crop growth period is, therefore, vital important. Studies on weed control in kodo millet were bare minimum and needs to develop integration of chemical weed management along with hand weeding for this crop, since, these crop is considered as one of the nutria cereals. In this context, a research programme was formulated to evolve weed management through herbicide and hand weeding for higher productivity in kodo millet to achieve higher productivity. extent as the solvating power (which is driven by density) of SCFs can be altered over a wide range by changing the pressure, the temperature or both.

Materials and Methods
Field experiment was conducted at Tamil Nadu Agricultural University, Coimbatore during *kharif* 2014 to evaluate integrated weed management practices against control of complex weed flora in irrigated kodo millet.

The experiment was laid out in randomized block design with three replications. The treatments comprised of different weed management practices *viz*., PE pendimethalin 500 g/ha *fb* (followed by) HW on 40 DAS (Days After Sowing); PE bensulfuron + pretilachlor 660 g/ha; PE isoproturon 500 g/ha; PE pendimethalin 500 g/ha *fb* twin wheel hoe weeder weeding at 40 DAS; PE bensulfuron + pretilachlor 660 g/ha *fb* twin wheel hoe weeder weeding at 40 DAS; PE isoproturon 500 g/ha *fb* twin wheel hoe weeder weeding at 40 DAS; PE isoproturon 750 g/ha *fb* HW at 40 DAS; Hand weeding twice at 20 and 40 DAS; Twin wheel hoe weeder weeding at 20 and 40 DAS; Weed free check and Unweeded control.

Observations were recorded on weed characters like weed flora, weed density, dry weight as suggested by Burnside and Wicks (1965) [5] and Weed control efficiency (WCE) was worked out on the basis of weed dry weight recorded in each treatment at 20, 40 and 60 DAS using the formula suggested by Mani *et al*. (1973) [6].

$$WCE\ (\%) = x\ 100 \quad \frac{WDWc - WDWt}{WDWc}$$

Where,
WCE : Weed control efficiency in percentage,
WDWc : Dry weight of weeds in unweeded check (g/ m^2)
WDWt : Dry weight of weeds in respective treatment (g/ m^2)

Weed index was calculated by following the formula suggested by Gill and Vijayakumar (1966) [7]

$$WI = \frac{X - Y}{X} \times 100$$

Where,
X : Yield obtained in the weed free plot (kg/ ha)
Y : Yield obtained in the respective treated plot (kg/ ha)

Yield parameters like number of tillers/m^2, panicle length, number of grains/panicle and 1000 grain weight. Grain and straw yield of irrigated kodomillet were recorded to assess the effect of weed management treatments on crop productivity. Yield was expressed at 14 per cent moisture basis as suggested by Yoshida *et al*. (1976) [8]. After separating the grains, the left over straw was sun dried for 4 days and weighed separately.

The data on various characters studied during the course of investigation were statistically analysed as suggested by Dhamu and Ramamoorthy (2007) [9]. The data pretaining to weed density and dry weight showed high variation and were subjected to square root transformation $\sqrt{(X + 0.05)}$ and analyzed statistically.

Results and Discussion

Weed flora

The general weed flora of the experimental field during the cropping period primarily composed of grasses, sedge and broad leaved weeds. The weed flora of the experimental field consisted of *Brachiaria reptans, Acrachne racemosa, Dactyloctenium aegyptium, Panicum repens* under grasses, *Cyperus rotundus* under sedge and *Trianthema portulacastrum, Boerhaavia diffusa, Parthenium hysterophorus, Digera arvensis, Tribulus terrestris* under broad leaved weeds. Dominance of such wide spectrum of weeds was also reported by many workers (Ramamoorthy *et al*., 2002 [10]; Kumara *et al*., 2007 [11]; and Basavaraj patil *et al*., 2014) [12].

The predominant occurrence of these weed species in kodo millet could probably be attributed to the ecological adaptation and dominance of the above listed weeds in sandy clay loam soils of Coimbatore region. Among the weeds, sedge weed was predominant and constituted about 45.07 per cent followed by broad leaved weeds of 42.54 per cent, among them, *Trianthema portulacastrum* was the dominant species of about 20.84 per cent followed by *Parthenium hysterophorus* of 8.03 per cent. Next to broad leaved weeds, grassy weeds accounted for 12.39 per cent in which *Dactyloctenium aegyptium* was the dominant species 7.69 per cent than other species Channa naik *et al.*(2001) [13].

Weed density

Early growth stages of kodo millet is subjected to heavy weed infestation and posed to decline the growth and productivity of the crop. This resource utilizing factor could be addressed through integrated approach. The combination of chemical along with physical /mechanical method, preferably, pre emergence application of herbicide and hand weeding are the vital tool for effective weed control and cost effective weed management strategy in kodo millet.

Weed control treatments hysterically altered the density of weed species over weedy check. Considerable reduction in grass, sedge and broad-leaved weed density was observed by PE isoproturon at 750 g/ha along with HW on 40 DAS and hand weeding twice at 20 and 40 DAS. Application of PE isoproturon at 750 g/ha at pre-germinated as well as at early establishment of weeds in the crop found to control all types of weeds which dominated in the experimental field and significant reduction of the weed population at later stages might be due to hand weeding; because weeds were removed with the help of hand hoe, which makes the soil porus and creates favourable environment for crop growth in addition to effective control of weeds. Similar observations were also made by Adikant Pradhan and Sonboir (2009) [3] and Adikant Pradhan *et al*. (2010) [14] who have reported that PE isoproturon at 0.5 kh/ha *fb* two intercultivations and hand weeding had controlled complex weed flora and reduce the density of weeds (Table 1). Obviously unweeded control resulted in higher density of grasses, sedge and broad leaved weeds due to unmanaged and increased weed growth at all the crop growth stages which was in conformity with the findings of Prajapati *et al.* (2007) [4].

Weed dry weight

Weed dry weight is a vital parameter to assess the weed competitiveness over the crop growth and productivity. Sparse weeds with high biomass might be more competitive for crops than dense weeds with lesser dry matter. Due to enactment of weed control treatments, significant variations in weed dry weight were observed at 20, 40 and 60 DAS (Table 1). Considerable reduction in weed dry weight was recorded with hand weeding twice at 20 and 40 DAS, PE isoproturon at 750g/ha *fb* HW on 40 DAS and PE isoproturon at 500g/ha *fb* twin wheel hoe weeder at 40 DAS. This may be due to less total weed density during the cropping period. Consequent on the weed control treatments, the total dry weight of the weed species were lower in the above treatments than weedy check Adikant pradhan *et al*. (2012) [15].

Weed control efficiency

Weed control efficiency attests the magnitude of effective reduction of weed dry weight by different weed control treatments throughout the crop period (Fig.1). Among the weed management practices imposed, the weed control treatment with PE application of isoproturon 750g/ha *fb* HW on 40 DAS (T_7) registered significantly higher weed control efficiency (76.3, 80.2 and 90.0 per cent at 20, 40 and 60 DAS respectively).This is due to the reason that PE isoproturon controlled grasses, sedge weed and broad leaved weeds effectively. Similar observations were made by Prajapati *et al*. (2007) [4].

Weed index

Weed index is a measure of yield loss caused due to varying degree of weed competition compared to the relatively weed free condition throughout the crop period leading to higher productivity. It is the ultimate parameter towards appraisal of the superiority or inferiority of weed control treatments. In the present study, hand weeding twice on 20 and 40 DAS was the best treatment as it resulted with 7.06 per cent yield reduction. It was followed by isoproturon 750g/ha as pre-emergence with one hand weeding on 40 DAS (8.57 per cent). This is due to weed free environment condition and effective utilization of applied inputs and natural resources by the crop. The largest yield reduction was observed in unweeded control (Fig.8). Similar result was obtained by Prajapati *et al.* (2007) [4] who reported that largest yield reduction of 46.36 per cent recorded in unweeded check. (Figure 2)

Application of different herbicides with combinations at different doses and time had phytotoxicity effect on irrigated kodomillet. Among the herbicides, PE admixture of bensulfuron + pretilachlor 600 g/ha (T_2) showed slight phytotoxicity on crop on 5 DAHS (Scale 2). The symptom persisted even upto 15 DAHS. However the crop recovered fully on 30 DAHS. Other herbicides were found to be safe to the crop Teekam Singh *et.al.,* 2014 [16]. (Table 2).

Conclusion

From this experiment, it is concluded that reasonable reduction in the density of grass, sedge and broad leaved weed and noticeable reduction in weed dry weight followed by higher weed control efficiency and lower weed index were observed with PE isoproturon 500 g/ha *fb* hand weeding at 40 DAS.

Hence, pre emergence application of isoproturon 500 g/ha followed by hand weeding at 40 DAS found to be effective in reducing the density of weed species in irrigated kodo millet.

Table 1: Effect of pre emergence herbicide and manual weeding practices on Total Weed Density and dry weight in Irrigated Kodo millet (No. /m^2)

Treatment	Total weed density (No./m^2)			Total Weed Dry Weight (kg/ha)		
	20 DAS	20 DAS	20 DAS	20 DAS	40 DAS	60 DAS
PE pendimethalin 500 g/ha *fb* HW on 40 DAS	6.40 (40.52)	7.66 (58.22)	7.66 (58.22)	7.66 (58.22)	8.56 (72.73)	6.99 (48.34)
PE bensulfuron + pretilachlor 660 g/ha (RM)	8.30 (68.47)	8.43 (70.56)	8.43 (70.56)	8.43 (70.56)	10.67 (113.36)	9.90 (97.55)
PE isoproturon 500 g/ha	5.76 (32.70)	6.73 (44.74)	6.73 (44.74)	6.73 (44.74)	8.16 (66.06)	7.26 (52.18)
PE pendimethalin 500 g/ha *fb* Twin wheel hoe weeder weeding at 40 DAS	6.48 (41.55)	7.90 (61.91)	7.90 (61.91)	7.90 (61.91)	9.29 (85.72)	7.76 (59.77)
PE bensulfuron + pretilachlor 660 g/ha (RM) *fb* Twin wheel hoe weeder weeding at 40 DAS	8.70 (75.17)	8.29 (68.21)	8.29 (68.21)	8.29 (68.21)	10.10 (101.58)	9.75 (94.63)
PE isoproturon 500 g/ha *fb* Twin wheel hoe weeder weeding at 40 DAS	5.66 (31.57)	6.62 (43.39)	6.62 (43.39)	6.62 (43.39)	8.09 (64.89)	6.43 (40.84)
PE isoproturon 750 g/ha *fb* HW on 40 DAS	5.20 (26.52)	6.04 (35.95)	6.04 (35.95)	6.04 (35.95)	7.46 (55.11)	6.35 (39.88)
Hand Weeding twice at 20 and 40 DAS	10.33 (106.11)	12.11 (140.27)	12.11 (140.27)	12.11 (140.27)	7.03 (48.94)	6.02 (35.78)
Twin wheel hoe weeder weeding at 20 and 40 DAS	10.39 (107.46)	12.22 (148.82)	12.22 (148.82)	12.22 (148.82)	7.79 (61.17)	7.06 (49.35)
Weed free check	0.71 (00.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
Unweeded control	10.86 (117.44)	12.34 (151.85)	12.34 (151.85)	12.34 (151.85)	16.72 (279.02)	18.94 (358.33)
SEd	0.34	0.32	0.32	0.32	0.37	0.33
CD (P=0.05)	0.72	0.66	0.66	0.66	0.77	0.69

Figures in parenthesis are mean of original values; Data subjected to square root transformation

PE – Pre emergence, HW - Hand weeding, *fb* - followed by, DAS – Days after Sowing, RM – Ready Mix

Table 2: Effect of Integrated Weed Management practices on phytotoxicity rating of Irrigated Kodo millet

Treatment	3 DAHS	5 DAHS	7 DAHS	15 DAHS	30 DAHS
PE pendimethalin 500 g/ha *fb* HW on 40 DAS	0	0	0	0	0
PE bensulfuron + pretilachlor 660 g/ha (RM)	0	2	2	2	0
PE isoproturon 500 g/ha	0	0	0	0	0
PE pendimethalin 500 g/ha *fb* Twin wheel hoe weeder weeding at 40 DAS	0	0	0	0	0
PE bensulfuron + pretilachlor 660 g/ha (RM) *fb* Twin wheel hoe weeder weeding at 40 DAS	0	2	2	2	0
PE isoproturon 500 g/ha *fb* Twin wheel hoe weeder weeding at 40 DAS	0	0	0	0	0
PE isoproturon 750 g/ha *fb* HW on 40 DAS	0	0	0	0	0

PE – Pre emergence, HW - Hand weeding, *fb* – followed by, DAS – Days after Sowing, RM – Ready Mix

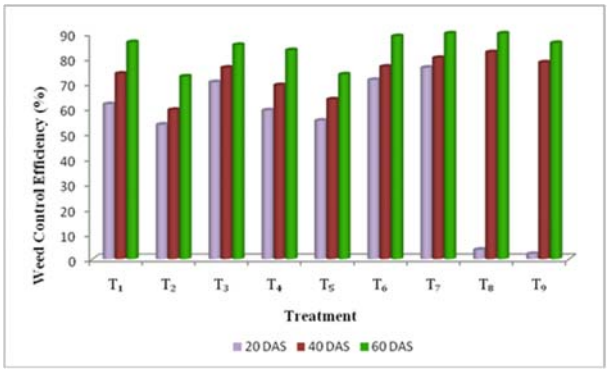

Fig 1: Effect of integrated weed management practices on weed control efficiency (%) in irrigated kodo millet

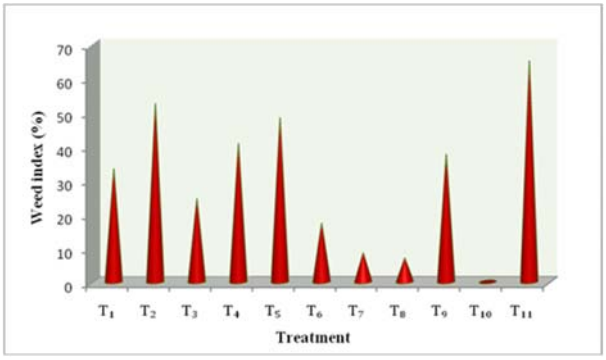

Fig 2: Effect of integrated weed management practices on weed index (%) in irrigated kodo millet

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