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Suitable weed management practices for dual purpose Sorghum K12 under Irrigated condition

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Abstract
A field experiment was investigated at Agricultural College and Research Institute, Killikulam for evaluating suitable weed management practices for dual purpose sorghum variety K 12 (*Sorghum bicolor* L.) under irrigated condition during *rabi* season, 2019-20. The experimental design used for the investigation was Randomized Block Design having three replications and twelve treatments. The weed management practices comprised of pre emergence herbicides namely atrazine @ 0.5 kg ha^{-1} and pendimethalin @ 0.5 kg ha^{-1}, post emergence herbicides *viz*., 2,4-D @ 0.5 kg ha^{-1} and metsulfuron methyl @ 6 g ha^{-1} with combination of hand weeding and mechanical weeding. Observations on weeds like weed flora, weed dry weight, weed density, weed control efficiency and on growth parameters like plant height, leaf length and breadth and yield parameters like grain and stover yield were documented. The field was infested with all three genera of weeds *viz*. grasses, broadleaved weeds and sedges. The results obtained from the experiment revealed that the weed density and weed dry weight was higher on the unweeded plot, which produced the lowest grain and stover yield of 1672 kg ha^{-1} and 5380 kg ha^{-1}, respectively. Application of atrazine @ 0.5 kg ha^{-1} as pre emergence + one hand weeding at 40 DAS showed a better control over the weeds with a weed control efficiency of 97.0 per cent, which ultimately resulted in higher yield producing 3998 kg ha^{-1} of grains and 11534 kg ha^{-1} of stover yield. However, this was on par with weed free check which produced the maximum yield compared to all the other treatments. The weeds accounts around 51.4% and 39.4% of grain and stover yield reduction, respectively.

Keywords: Dual purpose sorghum, weed management, weed dry matter, yield

Introduction
Sorghum (*Sorghum bicolor* (L.) Moench) is one of the principal food crop for the world's underprivileged and most food-insecure people and is a native of African regions. Sorghum is ranked fifth as an important cereal crop alongside wheat, rice, maize and barley. Sorghum in Northern India is popularly referred as **"**Jowar" and as **"**Cholam**"** in Tamil Nadu. Sorghum species occur mostly in the tropical and subtropical areas like African and Asian areas. Sorghum has a greater potential for production because of its expanding tolerance to various climatic conditions than any other millets and also is heat resistant, thus known as "camel crop." The reason is that the sorghum can remain dormant under stressful circumstances and can resume back its normal growth if situations become normal (Sujathamma, 2015) [13]. India is one of the notable country for its higher livestock population and its economic integration with farm production. The half of the losses in livestock productivity are due to the inadequacy in feed and fodder supply. Hence production practices must be well optimized and managed to satisfy the growing worldwide demand. (Bharathi *et al.*, 2020) [2]

Weeds are the most significant threat causing low sorghum productivity. Weeds are innately heavy competitors and those which remain competitive ever tend to overpower. Weeds are mainly the reducer of yield and are potentially more detrimental than insects or other crop pests in certain cases. The total economic loss was gauged at about 82,000 crores due to weeds in India. Sorghum crops alone contribute about 25.1 per cent to the Indian economy's loss due to weeds and which also caused 23.5-27.4% loss in the grain yield (Gharde *et al.*, 2018) [4]. A decline in crop yields in India in winter is about 31.5% and 22.7% and in summer and kharif it is about 36.5%, and in some cases, the crops may be ruined wholly. (Anonymous, 2007) [1].

Weeds are becoming resistant and difficult to control due to the constant use of a single weed control system (particularly herbicides).

In order to achieve efficient, sustainable and long-term weed control, adequate herbicide timing, rotation and combinations must be incorporated (Mishra *et al.*, 2016) [8]. The continued use of certain herbicide in the same crop in one particular field over a longer time often contributes to weed flora shifts. Also it may have the effect on quality of leaves which will be fed to the livestock. Hence it is necessary to consider the fodder quality while using the weed management practices. A unified approach to weed control may not maintain weeds below their economic levels and may lead to a change in weed flora, growth of resistance and environmental hazards. For weed management, thus, it is crucial to implement suitable technology, as weeds adapt strongly to management practices. Hence this study was carried out to evaluate the suitable weed management practices for dual purpose sorghum K 12 under irrigated condition.

Materials and Methods

The field experiment was conducted at Agricultural college and Research Institute (Tamil Nadu Agricultural University), Killikulam, Tamil Nadu during *rabi* season, 2019-20. The texture of the soil was sandy clay loam with pH of 8.04, EC of 0.45 dS m^{-1} and 3.38 g kg^{-1} of organic carbon content. The soil was low in available nitrogen (210 kg ha^{-1}), medium in available phosphorus (12.5 kg ha^{-1}) and medium in available potassium (242 kg ha^{-1}). The mean annual rainfall is 626.6 mm and the maximum and minimum temperature ranges from 34.2˚C and 22.5˚C, respectively. During the cropping period, the crop received 490.2 mm of rainfall in 31 rainy days and the maximum and minimum temperature ranges from 28.6ºC and 17.6˚C, respectively. The trail was laid out in Randomized Block Design (RBD) with twelve treatments and was replicated thrice. The treatment consists of different weed management techniques which includes T_1- Atrazine @ 0.5 kg ha^{-1} as pre emergence + One hand weeding at 40 DAS, T_2- Atrazine @ 0.5 kg ha^{-1} as pre emergence + metsulfuron methyl @ 6 g ha^{-1} as post emergence, T_3- Atrazine @ 0.5 kg ha^{-1} as pre emergence + 2,4-D @ 0.5 kg ha^{-1} as post emergence, T_4- Atrazine @ 0.5 kg ha^{-1} as pre emergence + One mechanical weeding at 40 DAS, T_5- Pendimethalin @ 0.5 kg ha^{-1} as pre emergence + One hand weeding at 40 DAS, T_6- Pendimethalin @ 0.5 kg ha^{-1} as pre emergence + metsulfuron methyl @ 6 g ha^{-1} as post emergence, T_7- Pendimethalin @ 0.5 kg ha^{-1} as pre emergence + 2,4-D @ 0.5 kg ha^{-1} as post emergence, T_8- Pendimethalin @ 0.5 kg ha^{-1} as pre emergence + One mechanical weeding at 40 DAS, T_9- Two hand weeding at 20 and 40 DAS, T_{10}- Two mechanial weeding at 20 and 40 DAS, T_{11}- weed free check, T_{12}- Unweeded control.

The test crop used for the study was K 12 sorghum, which is a dual purpose variety. The crop was cultivated under irrigated condition. NPK was given as urea, di ammonium phosphate and Muriate of potash, respectively. Weed samples were collected on 45 DAS for the assessment of weed density and weed dry weight. Weed samples were collected using quadrat of 0.25 m^2(50 cm x 50 cm) size at four places randomly. Weeds existed were detached, shade dried and then oven dried at 70ºC for 72 hours and the dry matter of weeds were assessed. Others observations like crop growth and yield parameters were also recorded. Data on weed count were subjected to square-root transformation to normalize their distribution. The data were pooled and analyzed statistically for interpretation of the results. All the other agronomic practices were made uniformly for all treatments.

Results and Discussion

Effect of treatments on weed

Weed flora

The field was infested with all the three genera of weeds *viz.* grasses, sedges and broadleaved weeds. Among them 12 species of weeds were dominating. The dominating weeds were *Echinochloa colona*, *Cynodon dactylon*, *Digitaria sanguinalis* among grasses; *Cyperus rotundus* among sedges; *Eclipta alba*, *Cleome viscosa*, *Cardiospermum halicacabum*, *Convolvulus arvensis*, *Ludwigia decurens*, *Phlyanthus niruri and Euphorbia hirta* among broadleaved weeds.

Weed density

The different weed control methods have a profound effect on the total weed density. The weed free plot recorded lower total weed density of 0.71 than all other treatments (Table 1.). Similar results have been obtained by Sukpreet Singh *et al.*, 2019. The weed free plot was followed by two hand weeding at 20 and 40 DAS (4.87). Among the chemical treatments, application of atrazine 0.5 kg ha^{-1} as pre emergence + one hand weeding at 40 DAS and atrazine @ 0.5 kg ha^{-1} as pre emergence + metsulfuron methyl @ 6 g ha^{-1} as post emergence were very effective in controlling the weeds which recorded a weed density of 5.42 and 6.81 respectively. Sorghum in very early stages of crop development grows slowly and competes weakly with weeds. This is the critical time and a small amount of weed in the field will cause a substantial reduction in yield (Saini *et al.*, 2018) [11]. Hence the above said treatments were effective in controlling the weeds in the earlier stages of the crop producing very low weed density. The weeds were very densely populated in the unweeded check. Herbicides in combination with good cultural practices would effectively reduce the density of the weed population in crop production (Greer and Denman, 1983) [5].

Weed dry matter

The dry matter of the weeds was immensely altered by the use of different weed control strategies (table 1.). As the level of herbicides or weed control practices increases there was a great decrease in the dry matter accumulation by weeds (Shakoor *et al.*, 2000) [12]. The weed free check was superior in reducing the weed dry weight with the value of 0.71. The treatment atrazine @ 0.5 kg ha^{-1} as pre emergence + one hand weeding at 40 DAS (3.06) succeeded the weed free check producing comparatively low weed dry weight.

Other than the above treatments, dry matter accumulation by the weeds was controlled effectively by two hand weeding @ 20 and 40 DAS, Pendimethalin @ 0.5 kg ha^{-1} as pre emergence + one hand weeding at 40 DAS and atrazine @ 0.5 kg ha^{-1} as pre emergence + metsulfuron methyl @ 6 g ha^{-1} as post emergence with the dry weight of 3.85, 4.68 and 4.84, respectively at 45 DAS. The latter two was on par with each other. Among the treatments other than weed free check, the treatments using atrazine in combination showed a great effect in reducing the dry weight. The reason for the low dry matter accumulation by the weeds in different weed management practices is because of their effectiveness in supressing the weeds. These results were in similarity with the findings of Shakoor *et al.*, 2000 [12].

The maximum weed dry matter was accumulated in the unweeded plots as the crops in the treatment was completely competed by the weeds because of the non-interference in the growth of weeds utilizing maximum resources (Deshmukh and Usadadia, 2017) [3].

Weed control efficiency

Weed control efficiency (WCE) denotes the magnitude of weed reduction due to weed control treatment (Mani *et al.*,1973) [7]. The weed control efficiency obtained as a result of different weed control strategies (Table.1) was in the range of 76.6 to 97.0 per cent. The weed free check is the most effectual weed control method compared to others with having 100.0% WCE value. Following this, atrazine @ 0.5 kg ha^{-1} as pre emergence + one hand weeding at 40 DAS, two hand weeding @ 20 and 40 DAS, pendimethalin @ 0.5 kg ha^{-1} as pre emergence + one hand weeding at 40 DAS and atrazine @ 0.5 kg ha^{-1} as pre emergence + metsulfuron methyl @ 6 g ha^{-1} as post emergence was very efficient in controlling the weeds with the efficiency of 97.0, 95.1, 92.9 and 92.1 per cent, respectively. The similar findings were reported by Pandey *et al.*, 2001 [9] and Thakur *et al.*, 2016 [15].

Effect of treatments on crop growth

Plant height

The growth performance of the crop will be indicated by the height of the plant which will be dependent on many factors. The plant height (Table 2.) of dual purpose sorghum differed significantly on 30, 60 DAS and at harvest by the weed management practices. The height of the sorghum elevated exponentially from sowing and reached its peak at harvest period.

At 30 DAS, the height of the dual purpose sorghum was maximum at the weed free plot with the height of 130.6 cm which was statistically comparable with the use of atrazine @ 0.5 kg ha^{-1} as pre emergence + one hand weeding at 40 DAS (127.8 cm). Similarly, the above treatment was on par with two hand weeding at 20 and 40 DAS (123.5 cm). The unweeded plot recorded the least height of 102.1 cm.

The tallest sorghum plants on 60 DAS and at harvest stage was noticed on weed free check (247.9 cm), which was statistically parallel among atrazine @ 0.5 kg ha^{-1} as pre emergence + one hand weeding at 40 DAS and atrazine @ 0.5 kg ha^{-1} as pre emergence + Metsulfuron methyl @ 6 g ha^{-1} as post emergence. The height of the plants was high on the above treatments is because that these treatments are effective in controlling the weeds hence offering less competition to the crop.

The shortest plant at harvest was observed on unweeded check with a plant height of 203.3 cm. The reason might be due to the competition offered by the weeds, the plant starts growing taller and thinner in earlier stages. Later, the growth becomes slower at a stage as there was a huge utilization of resource by the weeds as a result the plant height was small at the time of harvest (Patel *et al.*, 2014) [10].

Leaf length

The length of the leaf was high on weed free check (76.8 cm, 101.4 cm and 128.8 cm) during 30,60 DAS and at harvest, respectively. However, it was statistically similar with atrazine @ 0.5 kg ha^{-1} as pre emergence + one hand weeding at 40 DAS (76.4 cm, 100.8 cm and 128.1 cm), two hand weeding at 20 and 40 DAS (75.2 cm, 99.3 cm and 125.1 cm) and atrazine @ 0.5 kg ha^{-1} as pre emergence + Metsulfuron methyl @ 6 g ha^{-1} as post emergence (74.9 cm, 98.9 cm and 123.4 cm) respectively during 30, 60 DAS and at harvest. The shortest leaf on all three stages was recorded on unweeded check (56.3 cm, 74.4 cm and 93.0 cm respectively).

Effect of treatments on yield

The grain yield of the dual purpose sorghum was strikingly fluctuated by the adoption of various weed management practices (Table.3). The grain yield of the sorghum was high under weed free circumstance yielding 4243 kg ha^{-1} of grains. It was followed by application of atrazine @ 0.5 kg ha^{-1} as pre emergence + one hand weeding at 40 DAS witnessing the grain yield of 3998 kg ha^{-1}. Further, it was succeeded by two hand weeding @ 20 and 40 DAS with 3333 kg ha^{-1}, which was comparable with the application of atrazine @ 0.5 kg ha^{-1} as pre emergence + Metsulfuron methyl @ 6 g ha^{-1} as post emergence (3268 kg ha^{-1}).

In case of stover yield, the highest stover was produced on weed free check accounting 11993 kg ha^{-1} of stover. This was on similarity with the application of atrazine @ 0.5 kg ha^{-1} as pre emergence + one hand weeding at 40 DAS and atrazine @ 0.5 kg ha^{-1} as pre emergence + Metsulfuron methyl @ 6 g ha^{-1} as post emergence yielding 11534 kg ha^{-1} and 11297 kg ha^{-1} of stover yield, respectively. The above two treatments remained on par with two hand weeding @ 20 and 40 DAS which recorded 10758 kg ha^{-1}.

The higher yields obtained on the above treatments was due to the fact that there was reduced crop weed competition as lesser or no weeds had been observed on the above treatments. Because of that reason the availability of soil moisture, nutrients, light and other resources to the plants was very high and hence promoted higher yields. This concept was on similarity with the studies done by Thakur *et al.*, 2016 [15] and Ishya *et al.*, 2007 [6]. The lowest grain and stover yield was witnessed on the sorghum plants cultivated on unweeded situation, which recorded 1672 kg ha^{-1} of sorghum grains and stover yield recording 5380 kg ha^{-1}.

From this investigation, it was concluded that application of atrazine @ 0.5 kg ha^{-1} as pre emergence + one hand weeding at 40 DAS recorded lower weed competition and inturn higher plant growth and yield parameters. However, application of atrazine @ 0.5 kg ha^{-1} as pre emergence + Metsulfuron methyl @ 6 g ha^{-1} as post emergence also performed equally in the management of weeds in sorghum K 12 under irrigated condition.

Table 1: Effect of weed management practices on weed density (no. m^{-2}), weed dry weight (g m^{-2}) and weed control efficiency (%)

Treatment	Weed density (no. m^{-2})	Weed dry weight (g m^{-2})	Weed control efficiency (%)
T_1 -Atrazine @ 0.5 kg ha^{-1} as PE + One hand weeding at 40 DAS	5.42 (28.9)	3.06 (8.88)	97.0
T_2- Atrazine @ 0.5 kg ha^{-1} as PE + Metsulfuron methyl @ 6 g ha^{-1} as POE	6.81 (45.8)	4.84 (22.97)	92.1
T_3 - Atrazine @ 0.5 kg ha^{-1} as PE + 2,4-D @ 0.5kg ha^{-1} as POE	10.18 (103.2)	7.65 (57.99)	80.2
T_4 - Atrazine @ 0.5 kg ha^{-1} as PE + Mechanical weeding at 40 DAS	9.48 (89.4)	6.03 (35.87)	87.7
T_5 - Pendimethalin @ 0.5 kg ha^{-1} as PE + One hand weeding at 40 DAS	7.66 (58.1)	4.68 (20.86)	92.9
T_6 - Pendimethalin @ 0.5 kg ha^{-1} as PE + Metsulfuron methyl @ 6 g ha^{-1} as POE	14.85 (220.0)	7.89 (61.71)	78.9
T_7 - Pendimethalin @ 0.5 kg ha^{-1} as PE + 2,4-D @ 0.5kg ha^{-1} as POE	14.85 (220.0)	8.31 (68.59)	76.6
T_8 - Pendimethalin @ 0.5 kg ha^{-1} as PE + Mechanical weeding at 40 DAS	8.19 (66.6)	5.79 (33.01)	88.7
T_9 - Two hand weeding @ 20 and 40 DAS	4.87 (23.2)	3.85 (14.30)	95.1

T_{10}- Mechanical weeding @ 20 and 40 DAS	9.23 (84.6)	7.37 (53.88)	81.6
T_{11}- Weed free check	0.71 (0.0)	0.71 (0.00)	100.0
T_{12}- Unweeded control	24.30((589.8)	17.12 (292.58)	0.0
SEd	0.25	0.17	-
CD(P=0.05)	0.52	0.37	-

*Original values in the parenthesis were subjected to square root transformation ((x + 0.5)) before statistical analysis
Note: PE – Pre emergence application; POE- Post emergence application; DAS- Days after Sowing
WCE% - Data Not statistically analysed

Table 2: Effect of weed management practices on Plant height and leaf length (cm) of dual purpose sorghum K12 under irrigated conditions

Treatment	Plant height (cm)			Leaf Length (cm)		
	30DAS	60DAS	90DAS	30DAS	60DAS	90DAS
T_1 -Atrazine @ 0.5 kg ha^{-1} as PE + One hand weeding at 40 DAS	127.8	230.5	241.8	76.4	100.8	128.1
T_2- Atrazine @ 0.5 kg ha^{-1} as PE + Metsulfuron methyl @ 6 g ha^{-1} as POE	121.1	220.6	231.8	74.9	98.9	123.4
T_3 - Atrazine @ 0.5 kg ha^{-1} as PE + 2,4-D @ 0.5kg ha^{-1} as POE	104.7	198.5	209.0	60.5	79.8	103.1
T_4 - Atrazine @ 0.5 kg ha^{-1} as PE + Mechanical weeding at 40 DAS	111.9	203.6	217.9	60.9	80.4	104.2
T_5 - Pendimethalin @ 0.5 kg ha^{-1} as PE + One hand weeding at 40 DAS	120.1	212.4	223.1	59.8	78.9	102.3
T_6 - Pendimethalin @ 0.5 kg ha^{-1} as PE + Metsulfuron methyl @ 6 g ha^{-1} as POE	111.5	196.4	206.0	60.7	80.2	100.5
T_7 - Pendimethalin @ 0.5 kg ha^{-1} as PE + 2,4-D @ 0.5kg ha^{-1} as POE	106.5	199.2	209.7	56.5	74.6	94.4
T_8 - Pendimethalin @ 0.5 kg ha^{-1} as PE + Mechanical weeding at 40 DAS	118.9	209.5	218.3	69.4	91.6	116.1
T_9 - Two hand weeding @ 20 and 40 DAS	123.5	220.6	229.9	75.2	99.3	125.1
T_{10}- Mechanical weeding @ 20 and 40 DAS	118.1	205.1	217.7	63.5	83.8	106.7
T_{11}- Weed free check	130.6	236.9	247.9	76.8	101.4	128.8
T_{12}- Unweeded control	102.1	192.6	203.3	56.3	74.4	93.0
SEd	2.54	6.32	8.12	1.76	2.32	2.44
CD(P=0.05)	5.28	13.12	16.84	3.65	4.82	5.07

Note: PE – Pre emergence application; POE- Post emergence application; DAS- Days after Sowing

Table 3: Effect of weed management practices on Grain yield and Stover yield (kg ha^{-1}) of dual purpose sorghum K12 under irrigated conditions

Treatment	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
T_1 -Atrazine @ 0.5 kg ha^{-1} as PE + One hand weeding at 40 DAS	3998	11534
T_2- Atrazine @ 0.5 kg ha^{-1} as PE + Metsulfuron methyl @ 6 g ha^{-1} as POE	3268	11297
T_3 - Atrazine @ 0.5 kg ha^{-1} as PE + 2,4-D @ 0.5kg ha^{-1} as POE	2397	8231
T_4 - Atrazine @ 0.5 kg ha^{-1} as PE + Mechanical weeding at 40 DAS	3049	10050
T_5 - Pendimethalin @ 0.5 kg ha^{-1} as PE + One hand weeding at 40 DAS	2739	8736
T_6 - Pendimethalin @ 0.5 kg ha^{-1} as PE + Metsulfuron methyl @ 6 g ha^{-1} as POE	2334	8179
T_7 - Pendimethalin @ 0.5 kg ha^{-1} as PE + 2,4-D @ 0.5kg ha^{-1} as POE	2351	8276
T_8 - Pendimethalin @ 0.5 kg ha^{-1} as PE + Mechanical weeding at 40 DAS	2548	8686
T_9 - Two hand weeding @ 20 and 40 DAS	3333	10758
T_{10}- Mechanical weeding @ 20 and 40 DAS	2764	9211
T_{11}- Weed free check	4243	11993
T_{12}- Unweeded control	1672	5380
SEd	124	521
CD(P=0.05)	259	1081

Note: PE – Pre emergence application; POE- Post emergence application; DAS- Days after Sowing

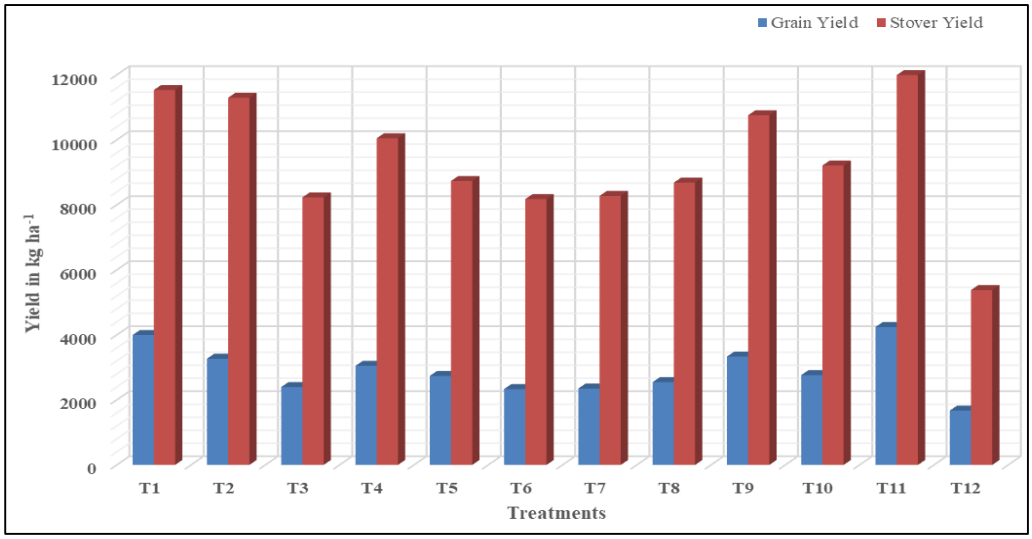

Fig 1: Effect of weed management practices on grain and stover yield of dual purpose sorghum K 12 under irrigated condition

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