Orginal research article

Impact of Live mulch, Brown manuring and Herbicides on Growth and Yield of Sorghum (*Sorghum bicolor* (L.) Moench) in Southern midland zone of Kerala, India

ABSTRACT

A field experiment was conducted during the *rabi* season of 2023 at the Farming System Research Station, Sadanandapuram, Kerala, to evaluate the effects of live mulch, brown manuring and herbicides effect as weed management method on growth and yield of sorghum. The experiment was conducted in a randomized block design with ten treatments, replicated thrice. The treatments included: Broadcasting cowpea seeds @ 15 kg ha $^{-1}$ *fb* live mulch at 25 DAS, Broadcasting cowpea seeds @ 30 kg ha $^{-1}$ *fb* live mulch at 25 DAS, Broadcasting cowpea seeds @ 15 kg ha $^{-1}$ *fb* brown manuring with 2,4-D 1 kg ha^{-1} at 20 DAS, Broadcasting cowpea seeds @ 30 kg ha $^{-1}$ *fb* brown manuring with 2,4-D 1 kg ha^{-1} at 20 DAS, PE pretilachlor 0.75 kg ha^{-1}*fb* one HW at 25 DAS, fenoxaprop-p-ethyl 0.06 kg ha^{-1} at 20 DAS, T_7:PoE 2,4-D 1 kg ha^{-1} at 20 DAS, HW at 20 DAS, Weed free control and Weedy check. Among the treatments, broadcasting cowpea seeds at 30 kg ha^{-1} followed by live mulch at 25 DAS (T_2) resulted the higher growth parameters, including plant height , number of leaves per plant, and dry matter production at 45 DAS and harvest. Leaf area per plant and leaf area index were also significantly higher in T_2 at 30 and 45 DAS. Yield attributes, such as panicle length, number of grains per panicle , grain weight per panicle, grain yield, stover yield and harvest index were higher in T_2. Broadcasting cowpea seeds @ 30 kg ha $^{-1}$*fb* brown manuring with 2,4-D 1 kg ha^{-1} at 20 DAS, pre-emergence pretilachlor 0.75 kg ha^{-1} *fb* hand weeding at 25 DAS, post-emergence

fenoxaprop-p-ethyl 0.06 kg ha^{-1} at 20 DAS and weed free control performed statistically comparable with T_2 in terms of growth and yield attributes.

Key words: *sorghum, live mulch, brown manuring, pre and post emergent herbicides, growth, grain yield, stover*

1. INTRODUCTION

Sorghum, also known as great millet, Indian millet, or jowar, is highly valued for its versatility, serving as a grain, forage, and sweet crop. It is the fifth largest cereal crop in the world. Nutritionally, sorghum is abundant in carbohydrates (70.7%), protein (10.4%), fat (3.1%), fibre (2.0%), calcium, iron, vitamin B, and niacin [1]. Sorghum is used in the production of edible oil, starch, dextrose, alcoholic beverages, and can substitute wheat in making bread, pasta, cookies, and other baked goods. It is a safe food grain and an excellent alternative for individuals with celiac disease due to its gluten-free nature [2].

India was the fifth-largest producer of sorghum, with a total production of 4.23 million tons across 3.9 million hectares [3]. Maharashtra and Karnataka contribute to 57.2% of India's sorghum production.

Intense weed pressure can significantly diminish grain and stover yields of sorghum. The initial slow growth rate and wide space between plants are the shortfalls being utilized by weeds to hinder growth of sorghum [4]. Sorghum is relatively a poor competitor against weeds especially during the early growth stages due to their slow initial growth and wider spacing. Yield loss due to weeds in sorghum varies from 5 to 74 per cent depending on climatic, edaphic and biotic factors.

Live mulch (living mulch) is cover crops grown simultaneously with and in close proximity to crops. Advantages of living mulches over dead cover crops may include increased weed suppression, reduced erosion and leaching, better soil health, and greater resource-use efficiency. Moreover live mulches may include enhanced agroecosystem biodiversity and suitability for a wider range of cropping systems [5].

Brown manuring is a version of green manuring where fast growing crops are grown in standing crops as inter crop and later destroying them with the help of herbicide for manuring where the plant residues are left standing in the field along with the main crop without incorporation / in-situ ploughing until its residues act as mulch leading to suppress weeds besides adding organic manure. The post-emergence herbicide spray on green leaves of fast growing crops resulting in loss of chlorophyll in leaves showing brown in colour is referred to as brown manuring [6].

Considering these facts the present research was conducted to find out the effect of different weed management on growth, grain and stover yields in sorghum.

2. MATERIALS AND METHODS

2.1 Location

The experiment was laid out at Farming Systems Research Station (FSRS), Sadanandapuram, Kottarakkara which enjoy southern midland agro ecological zone of Kerala during *rabi* 2023-24. The geographical location of site was at 8º 59' 2.0328" North latitude and 76º 48' 31.176" East longitude.

2.2 Soil

The soil type identified was sandy clay loam, characterized by extremely acidic (4.35), normal EC (0.24) and a high content of organic carbon (1.74%). The available nitrogen, phosphorus and potassium were 175.6 kg ha^{-1}, 43 kg ha^{-1}, 174.4 kg ha^{-1} respectively.

2.3 Plot Size

For this study, a total of 30 plots were used with each gross plot size 5.4 m x 3.0 m and net plot of 3.6 m x 2.4 m separated with bund space of 40 cm.

2.4 Crop Variety

The sorghum culture TNS 648 was released by the Department of Millets, TNAU, Coimbatore in 2020 and released as sorghum CO 32 was used for the study.

2.5 Herbicides

Pre-emergent herbicide pretilachlor (Trade name: Rifit 50 EC) and Post-emergent herbicides like 2,4-D (Trade name: 2,4-D Agan 80 WP) and fenoxaprop-p-ethyl (Trade name: Ricestar 6.9 EC) were used for the experiment.

Pretilachlor (2-chloro-N-(2,6-diethylphenyl)-N-(2-propoxyethyl) acetamide) belongs to chemical group of Chloroacetamide selected as pre emergent which control grasses, sedges and broad leaf weeds. 2,4-D Sodium salt belongs to phenoxy acids applied as post emergent which inhibit broad leaf weeds. Fenoxaprop-p-ethyl belongs to propionate chemical group is a selective post emergent herbicide which inhibits the acetyl coenzyme A carboxylase in the plant chloroplast leads to disrupting the synthesis of fatty acids in grass weeds.

2.6 Treatment Details

Ten treatments comprising of weed management practices *viz.*, T_1: Broadcasting cowpea seeds @ 15 kg ha $^{-1}$ *fb* live mulch at 25 DAS , T_2:Broadcasting cowpea seeds @ 30 kg ha $^{-1}$ *fb* live mulch at 25 DAS, T_3: Broadcasting cowpea seeds @ 15 kg ha $^{-1}$ *fb* brown manuring with 2,4-D 1 kg ha^{-1} at 20 DAS, T_4: Broadcasting cowpea seeds @ 30 kg ha $^{-1}$ *fb* brown manuring with 2,4-D 1 kg ha^{-1} at 20 DAS, T_5:PE pretilachlor 0.75 kg ha^{-1}*fb* one HW at 25 DAS, T_6:PDA fenoxaprop-p-ethyl 0.06 kg ha^{-1} at 20 DAS, T_7:PoE 2,4-D 1 kg ha^{-1} at 20 DAS, T_8:HW at 20 DAS, T_9:Weed free control (weeds removed by hand weeding as and when the weeds were observed) and T_{10}:Weedy check were evaluated in randomized block design with three replications. The crop was raised as per package of practices (POP) recommendation of Kerala Agricultural University.

2.7 Manures and fertilizers

Well decomposed farmyard manure (FYM) analyzing 0.5 per cent N, 0.18 per cent P_2O_5 and 0.49 per cent K_2O was applied as organic source. Fertilizers were applied in the form of urea (46% N), rajphos (18% P_2O_5), and muriate of potash (60 % K_2O) were used as the sources of NPK as per the package of practices recommendations of Kerala Agricultural University. Lime was applied as basal dose on soil test basis.

2.8 Live Mulching

The cowpea seeds were broadcasted at the same day of sowing and maintained. The cowpea crop and weeds present in the plot were uprooted and retained as live mulch in the plot itself at 25 DAS.

2.9 Brown Manuring

The cowpea seeds were broadcasted at the same day of sowing and 2,4-D were sprayed to the plot at 20 DAS. After the spraying resulted dried cowpea and weeds were retained in the plot till harvest.

2.10 Data Collection

Throughout the experimental period, observations on growth parameters of sorghum *viz.*, plant height, number of leaves per plant, leaf area per plant and dry matter production were taken from five randomly selected plants at 15, 30, 45 DAS and at harvest. For computing the yield parameters, days to 50 per cent flowering, panicle length, number of grains per panicle, grain weight per panicle, test weight, grain yield and stover yield were recorded from net plot at harvest.

2.11 Statistical Analysis

All the parameters were subjected for statistical analysis using GRAPES, a collection of shiny apps for agricultural research data analysis in R software developed by Department of Agricultural Statistics, College of Agriculture, Vellayani [7].

3. RESULTS AND DISCUSSION

3.1 Effect of Weed Management on Growth and Growth Parameters of Sorghum (Table 1)

Growth parameters (plant height, number of leaves plant^{-1}, leaf area plant^{-1}, leaf area index (LAI) and dry matter production plant^{-1}), were statistically influenced by the weed management in sorghum.

3.1.1 Plant height

Weed management had profound effect on plant height in sorghum at 45 DAS and at harvest. However, plant height at 15 and 30 DAS, failed to respond significantly to the weed management practices. At 45 DAS and at harvest, significant taller plants were observed in T_2 (Broadcasting cowpea seeds @ 30 kg ha $^{-1}$ *fb* live mulch at 25 DAS) (155.17 and 219.67 cm, respectively). However, at 45 DAS it were statistically comparable with T_5 (PE pretilachlor 0.75 kg ha^{-1}*fb* one HW at 25 DAS) (152.03 cm),T_9 (Weed free control) (149.03 cm) and T_6 (fenoxaprop-p-ethyl 0.06 kg ha^{-1} at 20 DAS) (148.43 cm)and at harvest, it were on par withT_5(PE pretilachlor 0.75 kg ha^{-1}*fb* one HW at 25 DAS) (210.03 cm), T_9 (Weed free control) (209.83 cm),T_6 (fenoxaprop-p-ethyl 0.06 kg ha^{-1} at 20 DAS) (199.63 cm) and T_1(Broadcasting cowpea seeds @ 15 kg ha $^{-1}$ *fb* live mulch at 25 DAS) (189.33 cm). The shortest plants at 45 DAS and at harvest were observed in T_{10} (weedy check) (126.57cm and 159.33 cm respectively).

Live mulches effectively controlled weeds by limiting their growth and reducing their capacity to deplete soil nutrients. Cowpea during the initial period acted as cover crop and later as live mulch declined the subsequent weed emergence. In addition, the presence of cowpea enhanced crop growth and made available the nutrient utilization to the favour of sorghum. The present investigation is harmonizing with findings of [8].

3.1.2 Number of leaves per plant

At 15 DAS and 30 DAS weed management was not significant different. However number of leaves per plant at 45 DAS and at harvest was influenced by weed management practices. At 45 DAS higher number of leaves per plant was observed with T_2(Broadcasting cowpea seeds @ 30 kg ha^{-1} *fb* live mulch at 25 DAS) (9.29) and it were statistically on par with T_1(Broadcasting cowpea seeds @ 15 kg ha^{-1} *fb* live mulch at 25 DAS) (9.11), T_9 (Weed free control) (8.78), T_8(HW at 20 DAS) (8.73), T_5(PE pretilachlor 0.75 kg ha^{-1}*fb* one HW at 25 DAS) (8.60) and T_4 (Broadcasting cowpea seeds @ 30 kg ha $^{-1}$ *fb* brown manuring with 2,4-D 1 kg ha^{-1} at 20 DAS) (8.53). The lowest number of leaves per plant was observed in weedy check (7.62). Significant higher number of leaves per plant at harvest registered with T_2 (Broadcasting cowpea seeds @ 30 kg ha^{-1} *fb* live mulch at 25 DAS) (12.35) and it were statistically comparable with T_9 (Weed free control) (12.09), T_6 (PDA of fenoxaprop-p-ethyl 0.06 kg ha^{-1} at 20 DAS) (11.73), T_5(PE pretilachlor 0.75 kg ha^{-1} *fb* one HW at 25 DAS) (11.65) and T_1(Broadcasting cowpea seeds @ 15 kg ha^{-1} *fb* live mulch at 25 DAS) (11.55). The lowest number of leaves per plant was recorded inT_{10} (weedy check) (7.62).

The live mulches or brown manuring with cowpea helped to prevent the weeds vigour which led to the robust growth of sorghum. Ability of cowpea for weed management also emphosised by [9] [10].

3.1.3 Leaf Area per Plant

Leaf area of sorghum was not affected significantly by weed management at 15 DAS. However, weed management had significant effect on leaf area of sorghum at 30 and 45 DAS. At 30 DAS higher leaf area per plant was observed in T_2(Broadcasting cowpea seeds @ 30 kg ha^{-1} *fb* live mulch at 25 DAS) (681.68 cm^2) and was comparable withT_9(Weed free control)(672.94 cm^2), T_8 (HW at 20 DAS) (0.77) (636.77cm^2), T_6 (fenoxaprop-p-ethyl 0.06 kg ha^{-1} at 20 DAS) (573.08cm^2) and T_5 (PE pretilachlor 0.75 kg ha^{-1}*fb* one HW at 25 DAS) (562.58cm^2). The observation on 45 DAS registered T_2 (Broadcasting cowpea seeds @ 30 kg ha^{-1} *fb* live mulch at 25 DAS) as higher leaf area per plant (4693.01cm^2) and it was statistically comparable with T_9 (Weed free control) (4550.15cm^2). At 30 DAS and 45 DAS the lowest leaf area in sorghum was noted in T_{10} (Weedy check) (351.09cm^2 and 2166.85cm^2 respectively).

The importance of integration of pretilachlor with other weed management strategies, could further optimize weed population resulted in ensuring sustainable sorghum production [11].

3.1.4 Leaf Area Index (LAI)

The weed management practices were not significantly affected the LAI of sorghum at 15 DAS. However at 30 DAS and 45 DAS, the weed management treatments significantly enhanced the LAI of sorghum. At 30 DAS, the treatment T_2 (Broadcasting cowpea seeds @ 30 kg ha^{-1} *fb* live mulch at 25 DAS) registered statistically higher LAI (1.01) and were comparable with T_9 (Weed free control) (0.99), T_8 (HW at 20 DAS) (0.94) and T_6 (fenoxaprop-p-ethyl 0.06 kg ha^{-1} at 20 DAS) (0.85). At 45 DAS, T_2 (Broadcasting cowpea seeds @ 30 kg ha^{-1} *fb* live mulch at 25 DAS) registered higher LAI (6.95) and was at par with T_9 (Weed free control) (6.74). During 30 DAS and 45 DAS the lowest LAI was recorded in T_{10} (weedy check) (0.62 and 3.21 respectively).

The enhanced photosynthetic area and number of leaves resulted from the weed management techniques led to the increase of LAI.

3.1.5 Dry matter production per plant

Weed management notably influenced the dry matter production per plant in sorghum at 30 DAS, 45 DAS and at harvest. However the observation on 15 DAS was non-significant (Fig.1).

At 30 DAS treatment T_9 (Weed free control) resulted in the highest dry matter production (0.89 g plant^{-1}) and it were comparable with T_5 (PE pretilachlor 0.75 kg ha^{-1} *fb* one HW at 25 DAS) (0.87 g plant^{-1}), T_2 (Broadcasting cowpea seeds @ 30 kg ha^{-1} *fb* live mulch at 25 DAS) (0.85 g plant^{-1}), T_6 (fenoxaprop-p-ethyl 0.06 kg ha^{-1} at 20 DAS) (0.84 g plant^{-1}), T_8 (HW at 20 DAS) (0.79 g plant^{-1}) and T_4 (Broadcasting cowpea seeds @ 30 kg ha^{-1} *fb* brown manuring with 2,4-D 1 kg ha^{-1} at 20 DAS) (0.74 g plant^{-1}). The lowest DMP was recorded in T_{10} (weedy check). The treatment T_2 (Broadcasting cowpea seeds @ 30 kg ha^{-1} *fb* live mulch at 25 DAS) resulted the higher DMP (25.87 g plant^{-1}) at 45 DAS and were comparable with T_9 (Weed free control)(25.38g plant^{-1}), T_5 (PE pretilachlor 0.75 kg ha^{-1}*fb* one HW at 25 DAS) (22.39g plant^{-1}),T_8 (HW at 20 DAS)(21.38g plant^{-1}), T_1 (Broadcasting cowpea seeds @ 15 kg ha $^{-1}$ *fb* live mulch at 25 DAS) (20.69g plant^{-1}) and T_6 (fenoxaprop-p-ethyl 0.06 kg ha^{-1} at 20 DAS) (19.96g plant^{-1}) and T_4 (Broadcasting cowpea seeds @ 30 kg ha $^{-1}$*fb* brown manuring with 2,4-D 1 kg ha^{-1} at 20 DAS) (19.43 g plant^{-1}). Weedy check registered the lowest DMP (14.75g plant^{-1}). The observation on harvest time indicated significant higher DMP with T_2 (Broadcasting cowpea seeds @ 30 kg ha^{-1} *fb* live mulch at 25 DAS) (71.49g plant^{-1}) and were comparable with T_4 (Broadcasting cowpea seeds @ 30 kg ha $^{-1}$*fb* brown manuring with 2,4-D 1 kg ha^{-1} at 20 DAS) (68.15 g plant^{-1}), T_9 (Weed free control) (64.83g plant^{-1}) and T_6 (fenoxaprop-p-ethyl 0.06 kg ha^{-1} at 20 DAS) (60.44g plant^{-1}). The lowest DMP was recorded in T_{10} (weedy check) (60.44g plant^{-1}).

Weed management techniques effectively controlled weeds by limiting their growth and nutrient removal which made the crop for competition free efficient nutrient absorption resulted the higher dry matter accumulation. The importance of weed management during the critical period for enhancement of dry matter were also emphasized by [12].

3.2 Effect of Weed Management on Yield and Yield Parameters of Sorghum (Table 2)

Yield attributes like days to 50% flowering, panicle length, Number of grains per panicle. Grain weight per panicle, grain yield, stover yield and harvest index were statistically influenced by the weed management in sorghum.

3.2.1 Days to 50 per cent flowering

Weed management had profound effect on days to 50 per cent flowering in sorghum. The average days to 50 percent flowering varied from 63.33 to 67.33 days in sorghum. The treatment T_9 (Weed free control) took lesser number of days (63.33) to 50 percent flowering. However it were statistically comparable withT_2 (Broadcasting cowpea seeds @ 30 kg ha^{-1}*fb* live mulch at 25 DAS) (63.67), T_5 (PE pretilachlor 0.75 kg ha^{-1}*fb* one HW at 25 DAS)(63.67), T_1 (Broadcasting cowpea seeds @ 15 kg ha^{-1}*fb* live mulch at 25 DAS)(64.00) and T_8 (HW at 20 DAS)(64.33) respectively. The more number of days (67.33) to 50 per cent flowering were taken by T_{10} (weedy check).

Brown manuring and pre emergent application of pretilachlor helped the crop to make the crop weed competition to the favour of sorghum which resulted the more nutrient absorption. The flowering cycle might have been triggered by the adequate and timely nutrient supply. [13] also observed that weed competition significantly delays the flowering and leads to reduction of crop yield.

3.2.2 Panicle length

The results revealed that the panicle length was significantly influenced by the weed management practices. Among the weed management treatments, the higher panicle length was observed in T_2 (Broadcasting cowpea seeds @ 30 kg ha^{-1}*fb* live mulch at 25 DAS) (27.23cm) and it was found to be comparable with treatments T_9 (Weed free control) (25.50cm), T_5 (PE pretilachlor 0.75 kg ha^{-1}*fb* one HW at 25 DAS) (24.67cm) and T_1 (Broadcasting cowpea seeds @ 15 kg ha^{-1}*fb* live mulch) (24.33cm). The lowest panicle length was recorded in T_{10} (weedy check) (21.00cm).

The present investigation was also in confirmatory with findings of [14] that suppression of weeds with pre-emergence application of bensulfuron methyl + pretilachlor 6.6% G @ 198 g a.i. ha^{-1}+ manual weeding at 30 DAS. Effective weed management resulted in noticeably greater yield attributes.

3.2.3 Number of grains per panicle

Weed management had significant effect on the number of grains per panicle of sorghum.

The treatment T_2 (Broadcasting cowpea seeds @ 30 kg ha^{-1}*fb* live mulch at 25 DAS) recorded the highest number of grains per panicle (2991.3) and it were on par with the treatments T_9 (Weed free control) (2972.3), T_6 (fenoxaprop-p-ethyl 0.06 kg ha^{-1} at 20 DAS) (2790.6) ,T_5 (PE pretilachlor 0.75 kg ha^{-1}*fb* one HW at 25 DAS) (2666.6) and T_1 (Broadcasting cowpea seeds @ 15 kg ha^{-1}*fb* live mulch at 25 DAS) (2488.3) and T_4 (Broadcasting cowpea seeds @ 30 kg ha^{-1}*fb* brown manuring with 2,4-D 1 kg ha^{-1} at 20 DAS) (2458.0). Weedy check (T_{10}) recorded the lowest number of grains per panicle in sorghum among different weed management practices (1561.6).

Suppression of weeds by post emergence application of fenoxaprop-p-ethyl led to the effective control of predominant grassy weed flora present which resulted in higher yield attributes and agreeing with findings of [15] [16]. The experimental field was predominated by grass flora, which was effectively suppressed by the post directed application of fenoxaprop-p-ethyl, while the sorghum crop showed zero phytotoxicity.

3.2.4 Grain weight per panicle

The weed management treatments significantly enhanced the grain weight per panicle of sorghum. The treatment T_2 (Broadcasting cowpea seeds @ 30 kg ha^{-1}*fb* live mulch) registered statistically higher grain weight per panicle (64.30 g) and it were comparable with the treatments T_4 (Broadcasting cowpea seeds @ 30 kg ha $^{-1}$*fb* brown manuring with 2,4-D 1 kg ha^{-1} at 20 DAS) (63.46 g), T_9 (Weed free control) (60.92g), T_5 (PE pretilachlor 0.75 kg ha^{-1}*fb* one HW at 25 DAS) (57.99g) and T_6 (fenoxaprop-p-ethyl 0.06 kg ha^{-1} at 20 DAS) (56.31g). The lowest grain weight per panicle (36.45g) in sorghum was recorded in T_{10} (weedy check).

Pre emergent application coupled with hand weeding or post emergent application of fenoxaprop-p-ethyl 0.06 kg ha^{-1} at 20 DAS or hand weeding helped the proper weed management at critical stage of sorghum and helped to realize the grain weight [17] also observed similar results.

3.2.5 Test weight

The test weight of sorghum grain was not significantly influenced by any of the weed management treatments.

3.2.6 Grain yield

The result revealed that weed management profoundly influenced the grain yield of sorghum. Among the weed management treatments, T_2 (Broadcasting cowpea seeds @ 30 kg ha^{-1} *fb* live mulch at 25 DAS) resulted in higher grain yield (2679kg ha^{-1}) which was statistically on par with T_9 (Weed free control)(2602 kg ha^{-1}), T_6 (fenoxaprop-p-ethyl 0.06 kg ha^{-1} at 20 DAS) (2567 kg ha^{-1}) and T_5(PE pretilachlor 0.75 kg ha^{-1}*fb* one HW at 25 DAS)(2530 kg ha^{-1}) and T_4 (Broadcasting cowpea seeds @ 30 kg ha $^{-1}$*fb* brown manuring with 2,4-D 1 kg ha^{-1} at 20 DAS) (2462 kg ha^{-1}). The treatment T_{10} (weedy check) recorded the lowest yield among the treatments (1952kg ha^{-1}).

This might be as a result of early flowering, higher number of grains per panicle and grain weight per panicle due to smothering of weeds by live mulch using cowpea crop. The uprooted and live mulches helped to cover the soil surface and arrested the subsequent emergence of new flushes of weeds. It could also be supported that the already removed nutrients by the weeds and cover crop of cowpea made available to the further crop growth and supplemented the nutrient demand of sorghum. The prevention of growth of subsequent weed flora also made advantageous to the crop. In addition to weed management live mulch provided a conducive microclimate for the beneficial microorganism, conservation of moisture. The increment in grain yield due to effective weed management emphasized by [18].

3.2.7 Stover yield

The results indicated that stover yield was also significantly influenced by weed management practices in sorghum (Fig.2). Significant higher stover yield (9896 kg ha^{-1}) was registered with T_2 (Broadcasting cowpea seeds @ 30 kg ha^{-1}*fb* live mulch at 25 DAS) and it was comparable with all the treatments other than T_1(Broadcasting cowpea seeds @ 15 kg ha $^{-1}$ *fb* live mulch at 25 DAS)(9050 kg ha^{-1}), T_7(PoE 2,4-D 1 kg ha^{-1} at 20 DAS)(8982 kg ha^{-1})and T_{10}(weedy check) recorded the lowest stover yield (8321kg ha^{-1}) among all the weed management treatments.

Higher growth attributes like plant height and accumulation of dry weight resulted from the effective weed management adopted . This reflected in the significant enhancement of stover yield. The present investigation supported by the findings of [19 [20] and [21].

3.2.8 Harvest index

Perusal of the data revealed that the weed management markedly influenced the harvest index. The treatment T_2 (Broadcasting cowpea seeds @ 30 kg ha^{-1} *fb* live mulch at 25 DAS) and T_9 (Weed free control) resulted in the highest harvest index (0.271) and was at par with T_6 (fenoxaprop-p-ethyl 0.06 kg ha^{-1} at 20 DAS) (0.269), T_5 (PE pretilachlor 0.75 kg ha^{-1} *fb* one HW at 25 DAS) (0.265) and T_4 (Broadcasting cowpea seeds @ 30 kg ha $^{-1}$ *fb* brown manuring with 2,4-D 1 kg ha^{-1} at 20 DAS) (0.262).The treatment T_{10} (Weedy check) resulted in the lowest harvest index (0.270).

The weed suppression by live mulches or post emergence application of fenoxaprop-p-ethyl helped to suppress the weed competition and enhanced nutrient status of soil. Weeds destroyed by herbicide might have become the food to microbes which encourage better absorption of nutrients and reflected in improved harvest index. [22] and [23] also found the importance of legumes in weed management increment of harvest index.

4. CONCLUSION

Broadcasting cowpea seeds at 30 kg ha^{-1} followed by live mulch at 25 DAS in sorghum resulted the higher growth parameters including plant height, number of leaves per plant, leaf area per plant, leaf area index and dry matter production. It also enhanced yield attributes, such as panicle length, number of grains per panicle, grain weight per panicle, grain yield, stover yield and harvest index. Broadcasting cowpea seeds @ 30 kg ha $^{-1}$ *fb* brown manuring with 2,4-D 1 kg ha^{-1} at 20 DAS, Pre-emergence application of pretilachlor 0.75 kg ha^{-1} followed by hand weeding at 25 DAS or post-emergence application of fenoxaprop-p-ethyl 0.06 kg ha^{-1} at 20 DAS were also viable option for increased growth, yield attributes and yield in sorghum.

Table 1. Effect of weed management practices on growth and growth parameters of sorghum.

Treatment	**Plant height (cm)**				**Number of leaves per plant**				**Leaf area per plant (cm^2)**			**Leaf area index**			**Dry matter production (g $plant^{-1}$)**			
	15 DAS	**30 DAS**	**45 DAS**	**At harvest**	**15 DAS**	**30 DAS**	**45 DAS**	**At harvest**	**15 DAS**	**30 DAS**	**45 DAS**	**15 DAS**	**30 DAS**	**45 DAS**	**15 DAS**	**30 DAS**	**45 DAS**	**At harvest**
T_1	29.72	56.77	141.27	189.33	4.89	6.22	9.11	11.55	86.31	516.31	3602.93	0.13	0.76	5.33	0.152	0.68	20.69	58.80
T_2	27.91	62.87	155.17	219.67	4.60	6.29	9.29	12.35	76.40	681.68	4693.01	0.11	1.01	6.95	0.139	0.85	25.87	71.49
T_3	28.18	55.60	134.37	181.57	4.82	6.29	8.50	10.90	78.25	498.98	2399.62	0.11	0.74	3.55	0.159	0.73	16.11	57.08
T_4	28.92	57.83	138.90	182.53	4.78	6.31	8.53	11.27	78.50	533.12	3000.62	0.11	0.79	4.44	0.162	0.74	18.43	68.15
T_5	32.35	64.57	152.03	210.03	5.01	6.30	8.60	11.65	89.28	562.58	3676.58	0.13	0.83	5.44	0.186	0.87	22.39	60.11
T_6	26.81	61.83	148.43	199.63	4.49	6.52	8.39	11.73	78.98	573.08	3571.19	0.11	0.85	5.29	0.178	0.84	19.96	60.44
T_7	28.32	55.40	133.67	166.33	4.78	6.40	8.22	10.67	83.65	417.99	3505.23	0.12	0.64	5.19	0.162	0.72	18.41	45.17
T_8	29.96	58.87	137.47	183.67	4.56	6.36	8.73	11.30	78.79	636.77	3654.44	0.11	0.94	5.41	0.158	0.79	21.38	57.15
T_9	26.98	61.50	149.03	209.83	4.39	6.46	8.78	12.09	85.56	672.94	4550.15	0.12	0.99	6.74	0.156	0.89	25.38	64.83
T_{10}	28.56	53.20	126.57	159.33	4.56	6.09	7.62	9.52	81.95	351.09	2166.85	0.12	0.62	3.21	0.174	0.63	14.75	42.82
SEm (±)	1.68	2.19	4.66	10.27	0.143	0.137	0.256	0.318	3.46	40.24	69.90	0.005	0.06	0.19	0.012	0.05	2.16	3.73
CD (0.05)	NS	NS	13.861	30.523	NS	NS	0.762	0.945	NS	119.564	207.712	NS	0.178	0.573	NS	0.149	6.436	11.088

*Note:T_1: Broadcasting cowpea seeds @ 15 kg ha^{-1} *fb* live mulch at 25 DAS, T_2:Broadcasting cowpea seeds @ 30 kg ha^{-1} *fb* live mulch at 25 DAS, T_3: Broadcasting cowpea seeds @ 15 kg ha^{-1} *fb* brown manuring with 2,4-D 1 kg ha^{-1} at 20 DAS, T_4: Broadcasting cowpea seeds @ 30 kg ha^{-1} *fb* brown manuring with 2,4-D 1 kg ha^{-1} at 20 DAS, T_5:PE pretilachlor 0.75 kg ha^{-1}*fb* one HW at 25 DAS, T_6: fenoxaprop-p-ethyl 0.06 kg ha^{-1} at 20 DAS, T_7:PoE 2,4-D 1 kg ha^{-1} at 20 DAS, T_8:HW at 20 DAS, T_9:Weed free control, T_{10}:Weedy check.

Table 2. Effect of weed management practices on yield and yield parameters of sorghum.

Treatment	Days to 50 per cent flowering	Panicle length (cm)	No. of grains per panicle	Grain weight per panicle (g)	Test weight (g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index
T_1	64.00	24.33	2488.3	50.39	22.17	2269	9050	0.251
T_2	63.67	27.23	2991.3	64.30	25.07	2679	9896	0.271
T_3	66.33	23.50	2338.6	52.60	22.47	2298	9153	0.251
T_4	65.67	24.07	2458.0	63.46	24.77	2462	9387	0.252
T_5	63.67	24.67	2666.6	57.99	23.93	2530	9556	0.265
T_6	64.67	23.67	2790.6	56.31	23.87	2567	9561	0.269
T_7	67.00	21.67	1867.0	44.47	22.30	2193	8982	0.245
T_8	64.33	24.17	2375.3	53.01	23.83	2333	9420	0.248
T_9	63.33	25.50	2972.3	60.92	24.23	2602	9605	0.271
T_{10}	67.33	21.00	1561.6	36.45	21.53	1952	8321	0.235
SEm (±)	0.36	1.02	201.92	3.58	1.49	77	278	0.006
CD (0.05)	1.065	3.024	599.95	10.628	NS	227.7	826.7	0.017

*Note:T_1: Broadcasting cowpea seeds @ 15 kg ha $^{-1}$ *fb* live mulch at 25 DAS, T_2:Broadcasting cowpea seeds @ 30 kg ha $^{-1}$ *fb* live mulch at 25 DAS, T_3: Broadcasting cowpea seeds @ 15 kg ha $^{-1}$ *fb* brown manuring with 2,4-D 1 kg ha^{-1} at 20 DAS, T_4: Broadcasting cowpea seeds @ 30 kg ha $^{-1}$ *fb* brown manuring with 2,4-D 1 kg ha^{-1} at 20 DAS, T_5:PE pretilachlor 0.75 kg ha^{-1}*fb* one HW at 25 DAS, T_6: fenoxaprop-p-ethyl 0.06 kg ha^{-1} at 20 DAS, T_7:PoE 2,4-D 1 kg ha^{-1} at 20 DAS, T_8:HW at 20 DAS, T_9:Weed free control, T_{10}:Weedy check

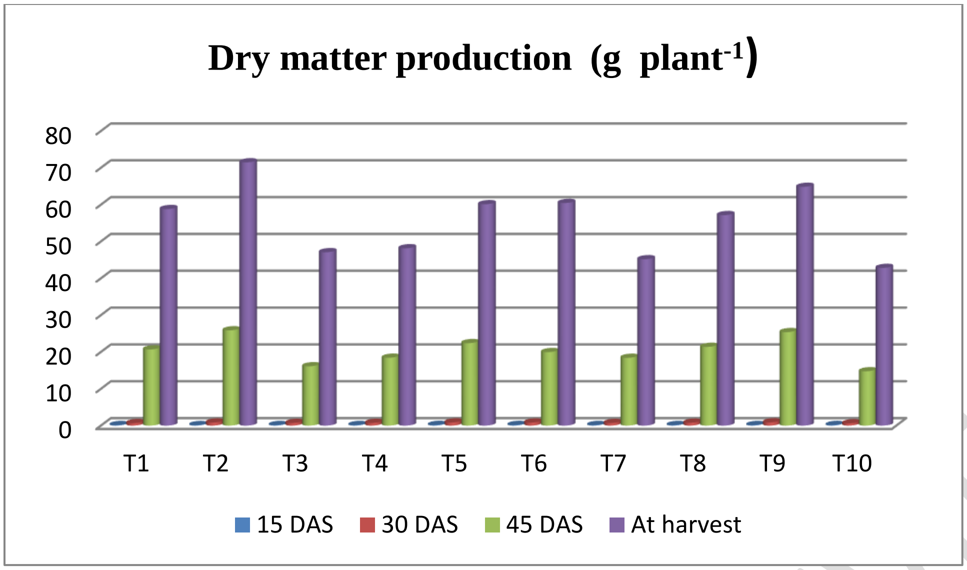

Fig. 1 . Effect of weed management practices on dry matter production of sorghum

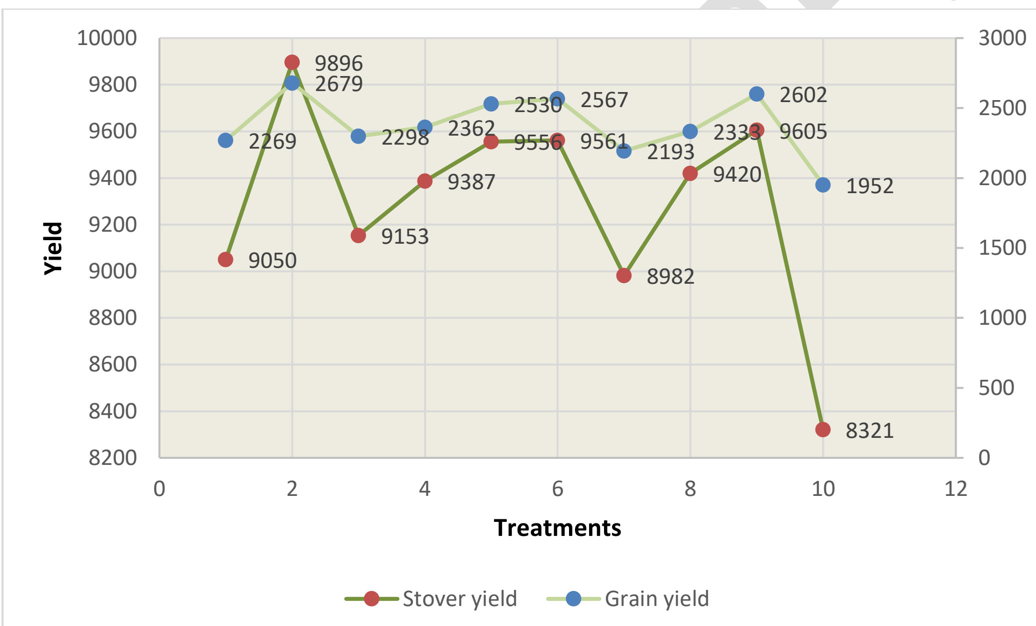

Fig 2. Effect of weed management practices on grain and stover yield in sorghum

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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Details of the AI usage are given below:

1.

2.

3.

REFERENCES

1. Tiwari H, Naresh RK, Bhatt R, Kumar Y, Das D, Kataria SK. Underutilized nutrient rich millets: Challenges and solutions for india's food and nutritional security: a review. Int. J. Plant Soil Sci.2023; 35(2):45-56 pp.
2. Kumar K, Kumar Y, Prabhakar K , Jayalakshmi M , Babu K, Vishnuvardhan K, Rao E. Effect of Mulching and Tillage Practices on Yield and Yield Attributes of Sorghum. Int. J. Environ. Climate Change. 2023; 13(11):1584-1590. https://doi.org/10.9734/ijecc/2023/v13i113312.
3. ANGRAU [Acharya N G Ranga Agricultural University]. *Crop Outlook Reports of Andhra Pradesh*. Acharya N G Ranga Agricultural University,Lam, Guntur, 2022;7p.
4. Mishra JS, Rao SS, Patil JV. Response of grain sorghum (*Sorghum bicolor*) cultivars to weed competition in semi-arid tropical India. *Indian J. Agric. Sci*; 2015;85(5): pp.688-694.

5. Bhaskar V, Westbrook AS, Bellinder RR, DiTommaso A. Integrated management of living mulches for weed control: A review. Weed Technol.2021; 35: 856–868. DOI: 10.1017/wet.2021.52.
6. Maitra S, Zaman A. Brown manuring, An effective technique for yield sustainability and weed management of cereal crops: A review. Int. J. Bioresource Sci. 2017; 4(1): 1-5. DOI**:** 10.5958/2454-9541.2017.00001.9.
7. Gopinath PP, Parsad R, Joseph B, Adarsh VS. GRAPES: General Rshiny Based Analysis Platform Empowered by Statistics.2020; [on-line]. Available: https://www.kaugrapes.com/home. version 1.0.0. DOI: 10.5281/zenodo.4923220.
8. Saudy H, El-Bially M, Ramadan K, El-Nasr E, El–Samad G. Potentiality of Soil Mulch and Sorghum Extract to Reduce the Biotic Stress of Weeds with Enhancing Yield and Nutrient Uptake of Maize Crop. *Gesunde Pflanzen*.2021; (73) 555 - 564. https://doi.org/10.1007/s10343-021-00577-z.
9. Mas-ud M, Dokurugu F, Kaba J. Effectiveness of cowpea (*Vigna unguiculata* L.) living mulch on weed suppression and yield of maize (*Zea mays* L.). *Open Agriculture*.2021; (6) 489 - 497. https://doi.org/10.1515/opag-2021-0031.
10. Reddy M, Chaudhary S, Kurdekar A, Sandeep S , Kumar M. Effect of Brown Manuring and Different Levels of Nutrients on Growth and Yield Attributes of Aerobic Rice (*Oryza sativa* L.). *Int, J, Environ. Climate. 2022*. https://doi.org/10.9734/ijecc/2022/v12i121450
11. Reis RM, Freitas MS, Silva DV, Pereira GAM, Passos ADJ, da Silva AF, da Silva AA, dos Reis MR. Effects of weed management and plant arrangements on yield index of sweet sorghum. Bioscience J. 2019;35(4)983-991 http://dx.doi.org/10.14393/BJ-v35n4a2019-36966
12. Renjan B, George S, Bindu B, Joseph AR. Soil seed bank dynamics of Blood grass (Isachne miliaceae Roth ex Roem et Schult) and associated weed flora on tillage, water regimes and herbicides in wet land rice ecosystem. Frontiers Crop Improve. 2022;10 (1): 611-616.
13. Korav S, Dhaka AK, Singh R , Premaradhya, N, Reddy GC. A study on crop weed competition in field crops. J. Pharmacogn. Phytochem. 2018;*7*(4), 3235-3240.

14. Yathisha K, Yogananda S, Thimmegowda P, Sanjay M, Prakash S. Growth and yield of direct seeded finger millet (*Eleusine coracana* L.) as influenced by weed management practices. J. Crop Weed. 2020; 16(3): 67-72.
15. Bhanwar S, Gathiye G, Verma V. Effect of herbicides on growth, yield and economics in soybean (*Glycine max* L.). *Int. J. Chem. Studies*. 2020;(8) 1151-1156. https://doi.org/10.22271/chemi.2020.v8.i3o.9355.
16. Kumar S, Singh M, Sanodiya P. Efficacy of doses of fenoxaprop-p-ethyl 69% EC and cyhalofop-butyl 10% EC on weed growth, yield and economics in transplanted rice (*Oryza sativa*). *Indian J. Agron*. 2022. https://doi.org/10.59797/ija.v67i1.94
17. Ramadevi S, Sagar GK, Subramanyam D, Kumar ARN. Weed management in transplanted finger millet with pre and post-emergence herbicides. Indian J. Weed Sci. 2021; 53(3): 297–299.
18. Renjan B, George S. Effect of tillage, water regimes and weed management methods on weeds and transplanted rice . Indian J. Weed Sci. 2018; 50 (1): 13-17
19. Chaudhary PV, Naresh R, Dhyani B, Chandra, M. Effect of Weed Management Practices on Weed Dynamics, Growth, Yield and Yield Attributes of Rice (*Oryza sativa* L.). Int. Res. J. Pure Applied Chem. 2020. https://doi.org/10.9734/irjpac/2020/v21i1930276.
20. Keerthi, DEP, Saravanane, R, Poonguzhalan, Nadaradjan, S. Muthukumarasamy, and Vijayakumar, S. . Effect of brown manuring practices on yield, nutrient dynamics and soil micro-flora in wet seeded rice in the coastal deltaic ecosystem." 2022; 519-524. https://doi.org/10.35709/ory.2022.59.4.15
21. Kumar S, Sridhar R, Monika S, Kumar A, Raghavan M , Tiwari H , Kumar A, Singh S, Yadav RA. Comprehensive review on millets: A potential source of energy and nutrients for health. Int. J. Environ. Clim. 2023; 13(9), 2531-2538
22. Mupangwa W, Twomlow S, Walker S. Reduced tillage, mulching and rotational effects on maize (*Zea mays* L.), cowpea (*Vigna unguiculata* (Walp) L.) and sorghum (*Sorghum bicolor* L. (Moench)) yields under semi-arid conditions. *Field Crops Res*. 2012;(132) 139-148. https://doi.org/10.1016/J.FCR.2012.02.020.
23. Egesa A , Njagi S, Muui C. Effect of Facilitative Interaction of Sorghum-Cowpea Intercrop on Sorghum Growth Rate and Yields. J. Environ. Agrl. Sci. 2017; (9) 50-58