# INTEGRATED WEED MANAGEMENT IN BUSH TYPE VEGETABLE COWPEA (*Vigna unguiculata* subsp. *unguiculata* (L.) Verdcourt)

*by*


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**THESIS**

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**2020**

## DECLARATION

I, hereby declare that this thesis entitled **"INTEGRATED WEED MANAGEMENT IN BUSH TYPE VEGETABLE COWPEA (*Vigna unguiculata* subsp. *unguiculata* (L.) Verdcourt"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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## CERTIFICATE

Certified that this thesis entitled **"INTEGRATED WEED MANAGEMENT IN BUSH TYPE VEGETABLE COWPEA (*Vigna unguiculata* subsp. *unguiculata* (L.) Verdcourt)"** is a record of research work done independently by Miss Sinchana J K under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| Ad | : | Absolute density |
| B: C ratio | : | Benefit cost ratio |
| BLW | : | Broad leaved weeds |
| Ca | : | Calcium |
| Co | : | Cobalt |
| $CO_2$ | : | Carbon di oxide |
| CD (0.05) | : | Critical difference at 5 % level |
| CGR | : | Crop Growth Rate |
| cm | : | Centimetre |
| $cm^2$ | : | Square centimeter |
| $cm^3$ | : | Cubic centimeter |
| CWC | : | Crop weed competition |
| CPCW | : | Critical period of crop weed |
| fb | : | Followed by |
| DAS | : | Days after sowing |
| DAP | : | Days after planting |
| DAT | : | Days after transplanting |
| DMP | : | Dry matter production |
| dS $m^{-1}$ | : | Deci siemens per meter |
| EC | : | Electrical Conductivity |
| e*t al.* | : | Co-workers/ Co-authors |
| Fe | : | Iron |
| Fig | : | Figure |
| FYM | : | Farm yard manure |

| | | |
|---|---|---|
| g | : | Gram |
| $g^{-1}$ | : | Per gram |
| $g\ m^{-2}\ day^{-1}$ | : | Gram per meter square per day |
| $g\ ha^{-1}$ | : | Gram per hectare |
| $g\ L^{-1}$ | : | Gram per litre |
| $g\ m^{-2}$ | : | Gram per meter square |
| $ha^{-1}$ | : | Per hectare |
| HI | : | Harvest index |
| $h^{-1}$ | : | Per hour |
| IIPR | : | Indian Institute of Pulse Research |
| K | : | Potassium |
| KAU | : | Kerala Agricultural University |
| kg | : | Kilogram |
| $kg\ ha^{-1}$ | : | Kilogram per hectare |
| $L^{-1}$ | : | Per litre |
| LAI | : | Leaf area index |
| $LD_{50}$ | : | Lethal dose |
| m | : | Meter |
| $m^{-2}$ | : | Per meter square |
| $mg\ g^{-1}$ | : | Milligram per gram |
| $mg\ g^{-1}\ day^{-1}$ | : | Milligram per gram per day |
| ml | : | Milli litter |
| $ml\ L^{-1}$ | : | Milli litter per litter |
| mm | : | Millimeter |
| MOP | : | Muriate of potash |
| Mg | : | Magnesium |
| Mn | : | Manganese |

| | | |
|---|---|---|
| N | : | Nitrogen |
| Na | : | Sodium |
| no.$m^2$ | : | Number per square meter |
| NS | : | Non significant |
| OC | : | Organic carbon |
| P | : | Phosphorus |
| pH | : | Potenz hydrogen |
| POP | : | Package of practices |
| ppm | : | Parts per million |
| Rd | : | Relative density |
| RBD | : | Randomized Block Design |
| RGR | : | Relative Growth Rate |
| RH | : | Relative density |
| S | : | Seed bed preparation |
| SC | : | Soluble Concentrate |
| SEm | : | Standard error of mean |
| SSB | : | Stale seed bed |
| Subsp. | : | Sub Species |
| t $ha^{-1}$ | : | Tonnes per hectare |
| TPF | : | Triphenyl formazan |
| *viz.* | : | Namely |
| W | : | Weed management practices |
| WAE | : | Week after emergence |
| WCE | : | Weed control efficiency |
| WDWC | : | Weed dry weight in control plot |
| WDWT | : | Weed dry weight in treated plot |
| WP | : | Wettable Powder |

| | | |
|---|---|---|
| WI | : | Weed index |
| WAT | : | Week after transplanting |

**LIST OF SYMBOLS**

| | | |
|---|---|---|
| % | : | Per cent |
| @ | : | at the rate of |
| ºC | : | Degree Celsius |
| µ | : | Micro |
| ₹ | : | Rupee |

# Introduction

# 1. INTRODUCTION

Legumes are the quick growing crop after the cereals. In India, legumes have a lead role in boosting the protein production as well as meeting the daily requirement of protein. Cowpea is one of the important multipurpose crops grown in the form of pulses, vegetables, green fodder and green manure. The pods are highly nutritious with a protein content of 21 to 33 per cent and leaves contain 27 to 43 per cent protein (Abudulai *et al*., 2016) and are the good sources of vitamin A, vitamin C, digestible protein, dietary fiber and minerals.

Vegetable cowpea is an important multipurpose leguminous crop which can be grown either as sole crop or intercrop. Though it is grown throughout the year irrespective of season, a huge yield gap exists both in production and productivity. Due to the slow initial development, the crop was subjected to severe weed infestation particularly in the earlier period of crop growth which emphasis the need to adopt good management practices.

Among the various biotic stress, weeds are the rigorous and prevalent biological constraints which causes severe yield loss. The initial slow growth of cowpea favoured the weeds to emerge first and gain competitive advantage over the crop. Owing to weed infestation an extent of 90 per cent yield loss recorded in cowpea (Frietas *et al*., 2009). Besides causing direct yield loss, also hinder farm activities and serves as alternate host to many pests.

Manual weeding is commonly adopted by the farmers for weed control in vegetable cowpea. Shortage of agricultural labour for weeding at the right time, high labour cost and abnormal weather conditions limit its efficacy. In order to reduce the dependence of human labour for weeding it is indispensable to develop an integrated approach involving both chemical and non- chemical methods.

Relaying on any single method of weed control will not help to gain sustainable and season long weed management. Integrated weed management approaches are necessary to bring the weed population below the economic threshold level and is an efficient tool to shift crop weed competition in favor of crop (Shweta and Singh, 2005).

Stale seed bed, a cultural method of weed control aims to deplete soil weed seed bank and also to flushes out germinating weed seeds prior to planting of crop and providing favorable environment for the early germination of crop.

Covering the soil surface with suitable mulch can reduce weed seed germination. Soil coverage with organic mulches is one of the non-chemical method of preventing weed infestation. Anzalone *et al.* (2010) found that organic mulch @ 1kg $m^{-2}$ with a thickness of 10 to 15 cm was sufficient to cover the soil and results in reduced weed density and enhanced crop yield.

Chemical method of weed control are the cheapest and economically feasible option due to the high efficacy of herbicides, easiness in application, large area coverage and involves less labour.

In this context the present study entitled "Integrated weed management in bush type vegetable cowpea (*Vigna unguiculata* subsp. *unguiculata* (L.) Verdcourt.)" was taken up with the following objective,

- To find out a cost-effective eco-friendly weed management practice for bush type vegetable cowpea.

# Review of literature

# 2. REVIEW OF LITERATURE

Cowpea is an important vegetable crop grown throughout India and Kerala. The pods are highly nutritive and are a good source of digestible protein, dietary fiber and vitamin A and C. In addition to this, the pods also contain Ca, P, Na, K, Mg, Fe, Zn, Mn and Co. The initial slow development and wider spacing necessitates weed control in earlier period of cowpea (Kandasamy, 1999). The weed infestation was more severe during rainy season and causes severe yield reduction. The critical period of crop weed competition (CWC) in cowpea was 20 to 30 days after sowing (DAS), this clearly point out the necessity of weed control during the first month of crop growth. The impact of weed interference on cowpea yield depends on the duration and stage at which the crop-weed interference take place. The season long competition resulted in 53 to 76 per cent yield reduction in cowpea (Gupta *et al.*, 2016).

The review of literature regarding the yield loss caused by weeds in cowpea, nutrient uptake by crop and weed, critical period of CWC, weed flora in cowpea, effect of stale seed bed (SSB), mulching, manual weeding, herbicides on weed management, effect of weed management practices on enzyme activity, nodulation, physiological parameters and economics are elaborated in this chapter.

## 2.1 YIELD LOSS CAUSED BY WEEDS IN COWPEA

Vegetable cowpea is found to be infested by a broad spectrum of weeds especially in the early stages. On account of their initial slow growth, cowpea is often subjected to weed infestation. Reduction in yield depends on the weed species, weed density and weed dry weight.

Wilson *et al.* (1980) opined that for every 100 kg weed dry weight, yield reduction of 208 kg ha$^{-1}$ occurred in cowpea. In cowpea more than 96 percent yield reduction was reported due to weed infestation (Amador-Ramirez *et al*., 2001).

Tripathi and Singh (2001) stated that in cowpea weeds caused 82 per cent reduction in yield. Medrano *et al.* (1973) opined that 50 to 60 per cent decline in yield owing to weed infestation; however, Li *et al*. (2004) reported that due to weed infestation yield loss in cowpea has been as high as 41 to 80 per cent but significant increase in yield was observed if weeds were controlled up to 45 DAS. Inadequate weed control caused 40 to 80 per yield reduction in cowpea (Sunday and Udensi, 2013).

Moody (1973) stated that weeds were removed within 5 weeks of crop emergence loss can be minimized. Irrespective of season, cowpea is infested by wide arrays of weeds and affecting the crop yield badly (Yadav *et al*., 1998). Depending on the cultivar and agro ecological condition yield losses in cowpea ranged from 25 to 76 per cent (Adigun *et al*., 2014; Gupta *et al*., 2016; Osipitan *et al*., 2016; Ugbe *et al*., 2016).

Muhammad *et al.* (2003) reported that weed infestation reduced the yield by 82 per cent, however, if weeds were controlled up to 45 DAS, significant increase in pod yield was observed. Freitas *et al*. (2009) reported 90 per cent reduction in final crop stand, number of pods per plant and grain yield due to weed interference in cowpea.

2.2 NUTRIENT UPTAKE BY CROP AND WEED

Singh *et al*. (1996) reported that maximum N and P uptake by green gram was observed if field was kept weed free from 25 to 45 DAS. Singh and Kolar (1994) found that N uptake by the weed infested soybean crop was 87.7 kg N $ha^{-1}$ however, weed free crop removed 132.7 kg N $ha^{-1}$. Pandya *et al.* (2005) also observed that in soybean, weeds removed 21.4 kg N $ha^{-1}$ and 3.1 kg P $ha^{-1}$. Mawalia *et al.* (2017) reported that weeds removed 49.3 kg N $ha^{-1}$, 19.7 kg P $ha^{-1}$and 44.7 kg K $ha^{-1}$ thereby depriving the same quantity of nutrients for crops.

Kaur *et al*. (2010) observed that pre emergence pendimethalin @ 0.75 kg $ha^{-1}$ recoded the lowest uptake of NPK by weeds and the highest NPK uptake in weedy check. Similarly, Choudhary *et al*. (2012) observed that significantly lower uptake by weeds was observed in pre emergence pendimethalin applied @1.5 kg $ha^{-1}$ *fb* hand weeding at 25 DAS.

Komal and Yadav (2015) observed that in green gram, imazethapyr had significant effect on reducing the weed biomass and resulted in lower NPK uptake by weeds and consequently higher NPK uptake by crop. In cowpea, hand weeding at 20 and 40 DAS recorded the lowest NPK uptake by weeds and the highest uptake in weedy check (Kujur *et al*., 2015). In green gram, imazethapyr @ 75 g ha$^{-1}$ + adjuvant @ 2 ml L$^{-1}$ of water recorded the lowest removal of NPK by weeds (Lal *et al.*, 2017). Poornima *et al*. (2018) reported that in green gram, two hand weeding at 20 and 40 DAS recorded significantly higher uptake of N, P and K and it was statistically on par with quizalofop-p-ethyl @ 50 g ha$^{-1}$ + imazethapyr @ 75 g ha$^{-1}$.

## 2.3 CRITICAL PERIOD OF CROP WEED COMPETITION (CPWC)

The critical period of weed control (CPWC) is the shortest duration of crop growth where crop must be kept weed-free for preventing the yield loss due to weed competition (Van Acker *et al*., 1993). If the weeds growth were checked during CPCW, the potential yield of crops can be maximized (Mishra, 1997; Tewari, 1999).

The yield reduction depends on the duration as well as the crop stage at which crop weed interference occurs (Knezevic *et al*., 2003). Knezevic and Datta (2015) opined that weed control after or before the CPCW does not contribute to potential yield of the crop

Medrano *et al.* (1973) revealed that 20 to 40 DAS was the CPCW in cowpea. Akinyemiju and Echendu (1987) observed that CPCW in cowpea varies from 10 to 45 DAS and in rainy season it may extend up to harvest stage (Patel *et al.*, 2002). Akobundu (2005) observed that initial 3 to 4 weeks were critical for weed competition in cowpea. Freitas *et al*. (2009) revealed that the CPCW in cowpea was 11 to 35 DAS. Sunday and Udensi (2013) opined that during the first three to four weeks of crop growth weed infestation will adversely affect the crop yield. Gupta *et al*. (2016) opined that 20 to 30 DAS was the CPCW in cowpea and presence of weeds during that period caused severe yield reduction. Cowpea is sensitive to weed competition especially at the early stage of crop development and the period from 14 to 40 DAS was considered to be critical for CWC (Osipitan *et al*., 2016).

## 2.4 WEED FLORA IN COWPEA

Tripathi and Singh (2001) mentioned that major weed flora in cowpea was *Sorghum halepens*e (6.9%), *Echinochloa crusgalli* (8.4%), *Cyperus rotundus* (12.8%), *Gnaphalium indicum* (14.4%), *Eleusine indica* (15.7%) and *Dactyloctenium aegyptium* (41.8%).

Singh and Prasad (1987) conducted field trails and observed that cowpea field was infested with various weeds like *Eragrostis japonica* (12.5%), *Cyperus rotundus* (15%), *Boerhavia diffusa* (22.7%) and *Echinochloa colonum* (32.1%). Akinyemjju and Echendu (1987) conducted field experiment in Nigeria and revealed that major weed flora associated with cowpea was *Imperata cylindrica, Talinum triangulare, Euphorbia heterophylla, Synedrella nodiflora*, *Ageratum conyzoides*, *Spigelia anthelmia*, *Amaranthus* spp, *Ipomea* spp and *Cynodon dactylon*.

During rainy season *Cyperus rotundus, Digitaria sanguinalis* and *Trianthema portulacastrum* were found to be the problematic weeds of various pulse crops (Shekkon *et al.,* 1993). Mathew and Sreenivasan (1998) revealed that during summer season cowpea field was dominated by dicotyledon weeds and during *Kharif* season, grasses and sedges were dominated.

## 2.6 EFFECT OF MULCHING ON WEED MANAGEMENT

Mulching apart from adding organic matter to the soil, prevents soil erosion and decreases the weed population in initial crop growth stage by hindering the weed emergence (Pereira *et al.,* 2011; Monquero *et al.,* 2009). Mulches suppress the weeds by blocking the sunlight or creating the environmental conditions which will prevent the germination, emergence and subsequent growth of weeds.

Pullaro *et al*. (2006) opined that when plant residue is used as mulch material, it indirectly reduces the weed seed bank and thereby reduces the weed emergence.

Organic mulches reduce the tillage operations and are more popular in cropping systems (Bilalis *et al.,* 2003). They play an important role in enhancing the crop yield by reducing the soil temperature, increasing the soil moisture level and lowering the weed density (Sinkeviciene *et al.,* 2009; Mahmood *et al.*, 2015).

Lanini *et al*. (2011) opined that mulching with organic materials to a thickness of 10 cm was found effective in controlling the weeds and degrade quickly. Straw, perennial weeds, water-hyacinth, crop residues obtained from perennial crop residues of banana, sugarcane straw, sugarcane bagasse, sawdust, newspaper and shredded paper can be used as organic mulches (Monks *et al.,* 1997, Silva *et al.*, 2015).

Anzalone *et al*. (2010) pointed out that organic mulch @ 1kg $m^{-2}$ was more beneficial in lowering the weed density by sufficiently cover the soil and increased the crop yield. Singh (2010) revealed that newspaper mulching significantly improved the yield of edible pea.

Mulching followed by herbicide application or manual weeding were found to be the cost-effective method of weed control in green gram (Singh, 2009; Kalhapure and Shete, 2013). Dust mulching was found effective in lowering the BLW and sedges (Verma *et al.,* 2016). Wheat straw, peat and wood chip mulches have strong influence on weed germination, but it is necessary to ensure that the mulching material should be free from weed seeds (Jodaugienė *et al*., 2006). Shamla *et al*. (2017) reported that newspaper mulch recoded higher WCE and was the best among other organic mulches in reducing the weed density and biomass in okra.

## 2.7 EFFECT OF SSB ON WEED MANAGEMENT

Stale seedbed is a way by which weeds seeds were allowed to germinate by giving a pre-sowing irrigation and emerged weeds were destroyed using non-selective herbicides or by pre-plant tillage practices (Gnanavel and Kathiresan, 2014; Singh, 2014). The method of seed bed preparation, weed species, method adopted to kill the emerged weeds, environmental condition and the duration influence the success of SSB in controlling the weeds (Singh, 2014).

Stale seed bed significantly reduced the viability of weed seeds like *Digitaria sanguinalis*, *Poa annua* and *Eleusine indica* in the top two cm soil layer (Standifer, 1980). In peanut (*Arachis hypogaea* L.), SSB with shallow tillage reduced the population of weeds compared to SSB with glyphosate application Johnson and Mullinix (1995). Adequate weed control and optimal yield can be obtained if SSB were prepared 20 to 30 days prior to the planting of crop (Lonsbary *et al.,* 2003). Riemens *et al*. (2007) opined that SSB with mechanical method of weed control effectively reduced the density of weeds and was equally effective to chemical method. Stale seed bed followed by one hand weeding recorded the highest gross margin in organic garden pea (Gopinath *et al*., 2009). In finger millet, SSB followed by inter cultivation at 20 and 35 days after planting (DAP) significantly reduced the density and dry weight of weeds (Patil *et al*., 2013).

## 2.8 EFFECT OF MANUAL WEEDING ON WEED MANAGEMENT

Manual weeding is the most common method adopted by the farmers to remove the weeds in vegetable cowpea. Due to high wage rate, non-availability of labourer's at right time and aberrant weather conditions limits its efficacy.

Prasad and Singh (1998) revealed that in *Rabi* onion, hand weeding at 30, 60 and 80 days after transplanting (DAT) recorded the highest bulb yield and profit. Similarly, Karle *et al*. (2010) opined that hand weeding at 20, 40 and 60 DAS registered the highest yield in brinjal. Rahman *et al.* (2011) reported that in onion manual weeding throughout the growing season provided a weed free environment and resulted in higher bulb yield.

During summer season two hand weeding at 20 and 40 DAS recorded the lowest DMP and higher seed yield in black gram (Singh, 2011). Adigun *et al*. (2014) reported that hand weeding after complete ground coverage and during the reproductive stage caused physical injury to the crop plant and resulted in significant reduction in pod yield in cowpea. In carrot, two hand weeding at 30 and 60 DAS recorded the maximum length, girth, fresh weight of roots and yield (19.92 t $ha^{-1}$) (Chaitanya *et al.*, 2014). In cowpea, weeds can be effectively managed by hand weeding at third and sixth weeks after sowing (WAS) (Anonymous, 2014). Two hand weeding at 25 and 50 DAS recorded significantly higher number of pods per plant and 1000 seed weight in black gram (Mansoori *et al*., 2015). Similarly, two hand weeding at 25 and 45 DAS recorded the highest number of pods per plant, test weight and grain yield in red gram (Pandit *et al*., 2016). Baraiya *et al*. (2017) revealed that two hand weeding at 30 and 60 DAS recorded minimum weed density and higher WCE of 97.67 per cent in okra. Two hand weeding at two and five weak after emergence (WAE) recorded the lowest weed dry weight, higher number of nodules per plant and yield components in cowpea (Mekonnen and Dessie., 2019).

## 2.9 EFFECT OF HERBICIDES ON WEED MANAGEMENT

Chemical weed control is the cheapest and economically viable option for weed control in crops due to high efficacy, large area coverage, easiness in application and in areas where intercultural operations is not possible due to shortage of labour. It reduces the cost of tillage operations for weed control, kills the weeds in situ without the dissemination of vegetative propagules and effectively controls brush weeds and perennials. Gianessi and Reigner (2006) reported that chemical method of weed control reduced the cost of production of crops by 20 per cent. For the best results herbicides should be integrated with other methods, it should not be considered as an alternative to other weed control methods. The efficacy of herbicides depends on the right selection of herbicide, method of application and application at recommended dose. Fontes *et al.* (2010) opined that chemical method of weed control was cost effective as compared to mechanical method especially hand weeding. Madukwe *et al*. (2012) observed that in cowpea, herbicide application at two to three leaf stage recorded the highest plant height, number of pods per plant and test weight as compared to hand weeding treatment. According to Ashiq and Aslam (2014) in pulses, chemical method of weed control enhanced the yield by 10 to 50 per cent.

Based on the time of herbicide application, herbicides are classified into pre emergence and post emergence herbicides. Pre emergence herbicides are usually applied before the emergence of crop and weed, prevent the germination of weed seeds by inhibiting the root growth, shoot growth or both. It will remain in the soil for a substantial period, usually 8 to 12 weeks. Post emergence herbicides are herbicides applied after the crop and weed emergence. Imazethapyr and quizalofop-p-ethyl are the most commonly applied post emergence herbicides in cowpea. Imazethapyr comes under imidazoline group and quizalofop-p-ethyl comes under aryloxyphenoxypropionic acid group. Both the herbicides exhibited low to no phytotoxicity symptoms in cowpea as applied as post emergence herbicide. Singh *et al*. (2014) opined that, to reduce the human labour for weeding and also to control the second flush of weeds there is a need of using post emergence herbicides in crops. Kumar *et al*. (2017) observed that for effective weed control in pulses, pre emergence pendimethalin can be followed by the application of post emergence herbicides.

### 2.9.1 Pre Emergence Diclosulam

Diclosulam, a pre emergence broad spectrum herbicide belongs to the group triazalopyrimidine inhibits acetolactate synthase enzyme in susceptible species. It has been reported that half-life of diclosulam varies from 16 to 87 days according to the prevailed environmental conditions (Lavorenti *et al*, 2003). The adsorption and degradation of diclosulam in the soil depends on the soil moisture and organic matter content (Rodrigeus and Almeida, 2011).

Diclosulam as pre emergence herbicide effectively suppress the weeds in peanut (Askew *et al.*, 1999; Bailey *et al*., 1999). Diclosulam at higher doses (20 and 26 g ha$^{-1}$) was very effective in controlling grassy and non-grassy weeds as compared to lower doses of 18 g ha$^{-1}$ (Singh *et al.*, 2009). It was also reported that diclosulam effectively controlled BLW and sedges compared to other pre emergence herbicides tested, *viz*., pendimethalin and fluchloralin. Application of diclosulam @ 18 g ha$^{-1}$ *fb* hand weeding at 20 DAS was identified as the best treatment in reducing the grassy and non-grassy weed population in soybean (Nainwal *et al*., 2010). Rodrigues and Almeida (2011) opined that in soybean, the rate of application of diclosulam may vary from 25 to 35 g ha$^{-1}$ which is low as compared to the dosage of other pre emergence herbicides. Diclosulam was more effective in reducing the weed interference during the initial period of crop growth (Oliveira *et al*., 2013).

Singh *et al*. (2009) revealed that pre emergence diclosulam @ 26 g ha$^{-1}$ recorded higher number of pods per plant and yield in soybean. Deepa *et al*. (2017) reported that pre plant surface application of diclosulam @ 17.5 g ha$^{-1}$ recorded the highest plant height and branches in green gram but it reduces the number of nodules and effective nodules.

### 2.9.2 Post Emergence Imazethapyr

Imazethapyr is a standard commercial herbicide having both pre emergence and post emergence action. Pre emergence imazethapyr did not have any adverse effect, but post emergence application may cause minor impact on yield due to stunting and slight chlorosis (Wilson and Miller, 1991). However, Nandan *et al.* (2011) observed that post emergence imazethapyr @ 25 g ha$^{-1}$ had no adverse effect on the growth characters of rainy season black gram and recorded similar grain yield as that of hand weeding treatment.

Richburg *et al.* (1996) observed that imazethapyr was found effective in controlling the *Cyperus rotundus* when they were applied to 5 to 20 cm tall weeds. Compared to hand weeding treatment, imazethapyr @ 75 g ha$^{-1}$ at 20 to 25 DAS recorded the highest pods per plant in soybean (Ram and Singh, 2011). Nirala *et al*. (2012) conducted field experiment and found that post emergence imazethapyr @ 25 g ha$^{-1}$ recorded the highest grain yield in black gram. Post emergence imazethapyr @ 63 g ha$^{-1}$ *fb* hand weeding at 30 DAS recorded the highest WCE in chickpea (Ratnam *et al.,* 2011). Post emergence imazethapyr at 50 to 75 g ha$^{-1}$ controlled weeds throughout the season without causing injury to soybean crop (Ram *et al.,* 2011). Gupta *et al*. (2016) observed that imazethapyr @ 40 g ha$^{-1}$ recorded the highest seed yield and WCE in cowpea. Yadav *et al*. (2016) reported that imazethapyr @ 75 g ha$^{-1}$ *fb* one hand weeding at 40 DAS was the best treatment for controlling weeds in fodder cowpea.

**2.9.3 Post Emergence Quizalofop-p-ethyl**

Quizalofop-p-ethyl belonging to aryloxyphenoxypropionic acid group is the commonly used post emergence grass effective herbicide for annual and perennial grassy weed control in pulses.

Quizalofop-p-ethyl applied @ 50 g ha$^{-1}$ was equally effective with two hand weeding treatment in terms of seed yield, net return and B:C ratio in black gram (Rao, 2011). Mundra and Maliwal (2012) observed that quizalofop-p-ethyl @ 50 g ha$^{-1}$ recorded the lowest density of grassy weeds in black gram compared to other tested herbicides. Pratap *et al*. (2016) revealed that quizalofop-ethyl @ 50 g ha$^{-1}$ at 30 DAS was very effective in reducing the density of weeds and was statistically on par with intercultural operation at 15 DAS *fb* application of imazethapyr @100 g ha$^{-1}$ at 30 DAS and inter cultural operations at 15 DAS *fb* application of quizalofop-p-ethyl @ 50 g ha$^{-1}$ at 30 DAS. In vegetable cowpea, quizalofop-ethyl @ 0.05 kg ha$^{-1}$ *fb* hand weeding at 40 DAS significantly reduced the weed density and DMP (Dinesh *et al*., 2015). Kumar *et al*. (2017) reported in green gram, post emergence quizalofop-p-ethyl @ 40 g $ha^{-1}$ *fb* one intercultural operation and one hand weeding at 40 DAS recorded comparable yield with weed free check.

## 2.10 EFFECT OF WEED MANAGEMENT PRACTICES ON DEHYDROGENASE AND UREASE ENZYME ACTIVITY

Soil dehydrogenase enzyme is one of the major oxidoreductase enzymes indicating the overall microbial activity of soil, since it occurs in all living microbial cells as intracellular enzyme. Urease enzyme hydrolyses urea into ammonia and $CO_2$ and can be used as a biological indicator to assess the soil pollution (Srinivasulu and Rangaswamy, 2014).

The amount and type of enzymes produced are influenced by agrochemicals which modify the inter relationship between the group of organisms (Cerevelli *et al.,* 1978). Soil dehydrogenase activity can be considered as a valuable criterion in determining the negative effects of herbicides on soil microbial population (Rossell *et al*., 1992). Soil enzyme activity can be used as a bio-indicator for the changes occur in the soil due to herbicide application since they react faster than the soil physical activity (Saha *et al.*, 2016).

Imazethapyr did not have any negative impact on urease activity in soil (Ramesh *et al*., 2000). Majumdar *et al.* (2010) revealed that quizalofop-p-ethyl inhibits the urease enzyme activity in the soil. Tank-mix application of pendimethalin @ 0.5 kg $ha^{-1}$ + imazethapyr @ 0.075 kg $ha^{-1}$ recorded increased dehydrogenase activity and microbial population in soil (Younesabadi *et al*., 2014). Shruthi *et al*. (2015) stated that pre emergence herbicide recorded higher dehydrogenase enzyme activity compared to non-herbicide treatments. Lal *et al*. (2017) reported that seven days after the application of imazethapyr @ 75 g $ha^{-1}$ + adjuvant @ 2.0 ml $ha^{-1}$ of water and quizalofop-p-ethyl @ 1000 ml $ha^{-1}$ recorded lower urease and dehydrogenase enzyme activity compared to untreated plots. However, the reduction in the urease and dehydrogenase activity in quizalofop-ethyl treated plot was lower than that of imazethapyr treated plots. Shilpa *et al***.** (2018) observed that imazethapyr @ 100 g $ha^{-1}$ recorded significantly lower dehydrogenase activity as well as urease enzyme activity compared to weedy check and weed free treatments.

## 2.11 EFFECT OF WEED MANAGEMENT PRACTICES ON NODULATION

Gupta and Gupta (1983) observed that grass mulching reduced the soil temperature and increased the nodulation in pulses. Surface mulching with wheat straw recorded higher number of nodules per plant, dry weight and nodule diameter in soybean (Siczek and Lipiec, 2011). The highest number of nodules per plant was noticed in organic mulch compared to black polyethylene mulch in cowpea (Dukare *et al.,* 2017). Dinesh *et al*. (2015) reported that mulching with slashed grass and black polythene recorded higher number of nodules.

Prahalad *et al*. (2015) reported that weed free treatment recorded the highest number of nodules per plant (34.96) and was statistically on par with hand weeding treatment. Deepa *et al.* (2017) reported that pre plant surface application of diclosulam herbicide @ 17.5 g $ha^{-1}$ did not hamper nodulation in green gram and can be considered as a safe dose. Pre emergence pendimethalin @ 1.0 kg $ha^{-1}$ *fb* post emergence quizalofop-p-ethyl and imazethapyr @ 50 g $ha^{-1}$ recorded higher number of nodules per plant in green gram (Muthuram *et al*., 2018). Herbicides *viz*., fenoxaprop-p-ethyl and quizalofop-p-ethyl recorded higher number of nodules and nodule dry weight per plant compared to oxyfluorfen and imazethapyr in chick pea (Raghavendra *et al*., 2017). Quizalofop-p ethyl @ 37.5 g $ha^{-1}$ recorded lower number of nodules per plant and nodule dry weight compared to hand weeding treatment (Singh *et al.,* 2017). Kumar *et al*. (2018a) reported that imazethapyr @ 80 and 100 g $ha^{-1}$ recorded higher number of nodules and nodule dry weight per plant in green gram.

## 2.12 EFFECT OF WEED MANAGEMENT PRACTICES ON PHYSIOLOGICAL PARAMETERS

Physiological parameters of crop were also found to be influenced by weed management practices. Veeraputhiran and Chinnusamy (2008) revealed that compared to application of imazethapyr at 14 DAS, application at 21 and 28 DAS recorded higher LAI and dry matter production in black gram. Gupta *et al*. (2014) observed that application of imazethapyr @ 25 and 40 g $ha^{-1}$ at 20 DAS were statistically on par with hand weeding treatment with respect to CGR at different intervals in urd grown under sub- tropical condition. Quizalofop-p-ethyl @ 37.5 g ha$^{-1}$ applied at 20 DAS and hand weeding twice at 30 and 40 DAS recorded maximum CGR (7 g m$^{-2}$ day$^{-1}$) and RGR (0.0234 g$^{-1}$ g$^{-1}$ day$^{-1}$) in garden pea (Rama *et al*., 2015). Imazethapyr @ 200 g ha$^{-1}$ recorded the highest CGR 13.14 g day$^{-1}$ and RGR (0.00442 g g$^{-1}$ day$^{-1}$) in green gram under different agri-horticulture systems (Shivran *et al.*, 2017).

Veeramani *et al*. (2006) stated that SSB with paraquat application appreciably increased the growth parameters, *viz*., LAI, CGR and RGR in irrigated cotton. Rice straw mulching to a depth of 0.1 m depth + one hand weeding at 6 week after sowing (WAS) significantly influenced the LAI, RGR and CGR in groundnut (Olayinka and Eteere, 2015). Bhadauria *et al*. (2019) observed that mulching increased the CGR and LAI up to 90 DAS and RGR values up to 60 DAS in cluster bean.

## 2.13 EFFECT OF WEED MANAGEMENT PRACTICES ON NET RETURNS AND B:C RATIO

Economic assessment of weed control treatments is of utmost importance for its acceptance in farmers level. High weed control efficiency (WCE) coupled with cost effectiveness should be the criterion for the selection of the best weed management treatment (Khaliq *et al*., 2011).

Imazethapyr @ 40 g ha$^{-1}$ recorded the highest net return (₹ 24,718) and B:C ratio (3.46) in cowpea grown under rainfed condition (Gupta *et al.*, 2016). In chickpea imazethapyr @ 30 g ha$^{-1}$ applied on 10 days after germination recorded the highest gross return, net return and B:C ratio as compared to other herbicidal treatments (Pandit *et al.*, 2016).

Post emergence quizalofop-p-ethyl @ 50 g ha$^{-1}$*fb* one hand weeding at 45 DAS recorded the highest B:C ratio (2.53) and net return (₹27,757) in lentil (Kumar *et al.*, 2018a). Kumar and Singh (2017) also revealed that post emergence quizalofop-p-ethyl + one hand weeding + one intercultural operation recorded the highest net return (₹23,709) and B:C ratio (4.21) in cowpea.

In chilli, straw mulching recorded the highest net return and B:C ratio (Sutagundi, 2000). Dust mulching registered the highest yield and B:C ratio (3.36) in green gram as compared to straw mulch and control (Verma *et al*., 2008). In chilli compared to paddy straw mulching, soybean straw mulching recorded the highest net return and B:C ratio (Prakash *et al.*, 2017).

Among the weed management practices, two hand weeding at 25 and 40 DAS recorded higher gross income (₹81,320.50 $ha^{-1}$), net return (₹ 31,388 $ha^{-1}$) and B:C ratio (1.63) in vegetable cowpea (Patil *et al*., 2014). Kujur *et al*. (2015) reported that hand weeding at 20 and 40 DAS recorded the highest net return in cowpea.

# MATERIALS AND METHODS

# 3. MATERIALS AND METHODS

Experiment entitled "Integrated weed management in bush type vegetable cowpea (*Vigna unguiculata* subsp. *unguiculata* (L.) Verdcourt)" was conducted at Coconut Research Station, Balaramapuram, Thiruvananthapuram district, Kerala during *Kharif* 2019. The main objective of the study was to find out a cost-effective ecofriendly weed management practice for bush type vegetable cowpea. Materials and methods adopted during the course of research work are presented below.

## 3.1. GENERAL DETAILS

### 3.1.1 Location

The field experiment was conducted at Coconut Research Station, Balarampuram, Thiruvananthapuram, Kerala which is located at 8° 22' 52' North latitude and 77 º 1' 47" East longitude and at an altitude of 9 m above mean sea level.

### 3.1.2 Climate

The climate of the experimental site is warm humid tropical. The data weekly rainfall, maximum and minimum temperature, relative humidity and evaporation prevailed during the cropping period are presented in Appendix-1 and graphically represented in Fig. 1.

### 3.1.3 Cropping Season

The experiment was conducted during 2019 *Kharif* season (14/05/2019 to 27/08/2019).

### 3.1.4 Soil

Soil texture of the experimental site is red loam, acidic in reaction. The chemical and physical properties of the experimental area are detailed in Table 1.

### 3.1.5 Cropping History

The crop was raised in the interrow space of 56 years old coconut planted at spacing of 7.5 m x 7.5 m having more than 70 percent light transmission. In the previous year banana crop was grown in the interrow space of coconut.

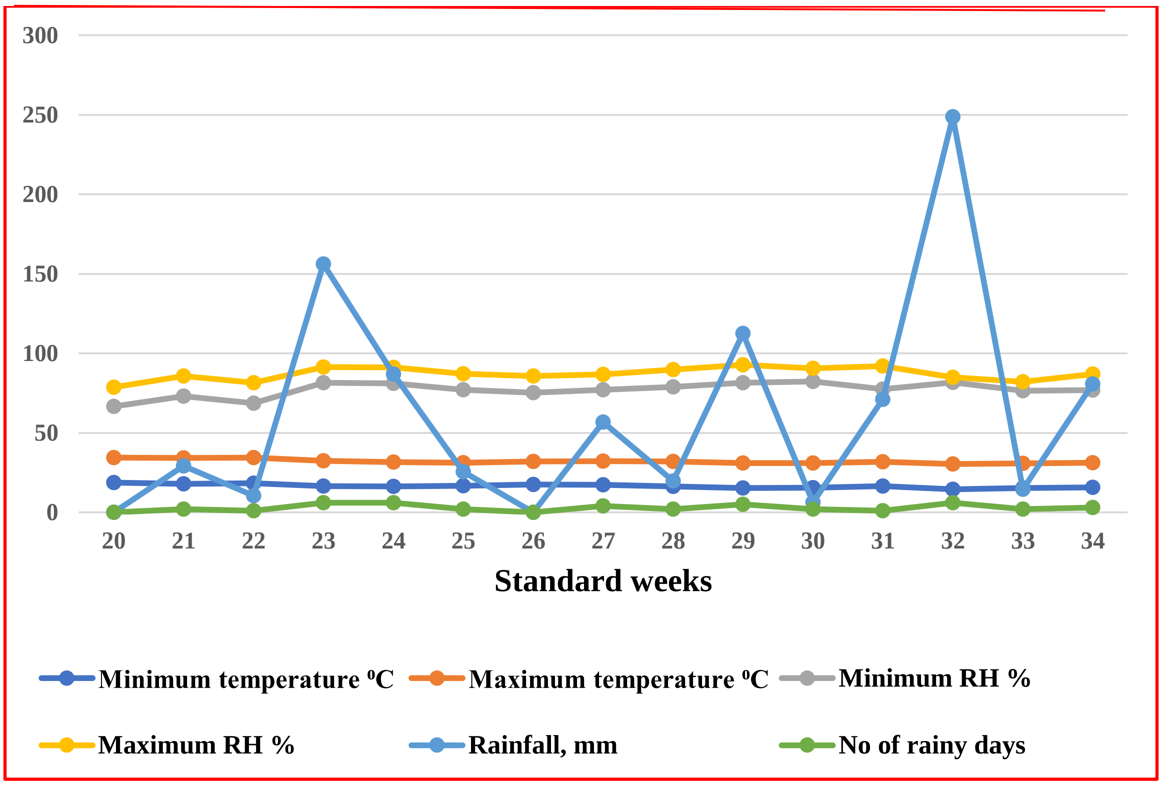


Fig 1. Weather data during the crop season (14/05/2019 to 26/08/2019)

**Table 1. Physico-chemical properties of soil before the experiment**

**A. Mechanical Composition**

| SL. No. | Fractions | Content in soil, per cent | Method |
|---|---|---|---|
| 1 | Sand | 66.43 | Bouyoucous hydrometer method (Bouyoucous, 1962) |
| 2 | Silt | 18.24 | |
| 3 | Clay | 15.33 | |

**B. Chemical properties**

| SL. No. | Parameters | Content | Method adopted |
|---|---|---|---|
| 1 | Soil reaction | 4.3 (Strongly acidic) | Soil water suspension of 1:2.5 and read in pH meter (Jackson, 1973) |
| 2. | EC ($dSm^{-1}$) | 0.1 (Normal) | Conductivity meter (1:2.5 soil water ratio) (Jackson, 1973) |
| 3. | Organic carbon (%) | 0.79 (High) | Walkley and Black rapid titration method (Walkley and Back, 1934) |
| 4. | Available N ($kg\ ha^{-1}$) | 206.30 (Low) | Alkaline permanganate method (Subbiah and Asija, 1956) |
| 5. | Available P ($kg\ ha^{-1}$) | 39.17 (High) | Brays colorimetric method (Jackson, 1973) |
| 6. | Available K ($kg\ ha^{-1}$) | 137.28 (Medium) | Ammonium acetate extract (Jackson, 1973) |

3.2. MATERIALS

**3.2.1 Crop Variety**

For the experiment, short duration variety, Bhagyalakshmy (80 days) released from College of Horticulture, Vellanikara, Thrissur was used as the test crop which is characterized by bushy growth habit with light green medium sized pods.

**3.2.2 Source of Seed**

The seeds for the experiment was procured from Coconut Research Station, Balaramapuram, Kerala, India.

**3.2.3 Manures and Fertilizers**

Dried powdered cow dung having N, $P_2O_5$ and $K_2O$ content of 0.45, 0.17 and 0.5 per cent, respectively was used as organic manure and urea, rajphos and muriate of potash were used as the source of NPK.

**3.2.4 Herbicides**

The toxicity and technical information of imazethapyr, quizalofop p-ethyl and diclosulam are given in Table 2.

3.3 METHODS

**3.3.1 Design and Lay out**

| | |
|---|---|
| Design | : RBD |
| Replication | : 3 |
| Treatments | : 2 x 8 =16 |
| Season | : *Kharif* 2019 |
| Spacing | : 30 cm x 15 cm |
| Gross plot size | : 3 m x 3 m |
| Net plot size | : 2.4 m x 2.4 m |
| Location | : Coconut Research Station, Balaramapura |

**Table 2. Technical information of the herbicides used in the study**

| Common name | Imazethapyr | Quizalofop-p-ethyl | Diclosulam |
|---|---|---|---|
| Chemical name | 2-4-5dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl | 2-{4-[(6-chloroquinoxalin-2-yl) oxy] phenoxy} propionic acid | N-(2,6-dichlorophenyl)-5-ethoxy-7-fluro (1,2,4) triazolo(1,5-C) pyrimidine-2-sulfonamide |
| Trade name | Pursuit® | Targa Super® | Strongarm® |
| Formulation | 10 % EC | 5 % EC | 84 WDG |
| Physical state, colour and odour | Solid, off white to tan, pungent | Liquid, light yellow clear aromatic | Solid, Beige colour, characteristic odour |
| Acute oral toxicity $LD_{50}$ (rat) | >5000 mg $kg^{-1}$ | >1210 mg $kg^{-1}$ | >5000 mg $kg^{-1}$ |
| Manufacturer | BASF | Dhanuka Agritech Ltd. Pune | Dow Agro Chemicals |

### 3.3.2 Treatment Details

Factor A : Seed bed preparation (S)

$S_1$ -Stale seed bed (SSB)

$S_2$ -No stale (Normal field preparation)

Factor B : Weed management practices (W)

$W_1$ - Dried banana leaf mulch @ 10 t $ha^{-1}$ alone

$W_2$ - Dried banana leaf mulch @ 10 t $ha^{-1}$ *fb* post emergence imazethapyr @ 50 g $ha^{-1}$ at 25 DAS

$W_3$ - Dried banana leaf mulch @ 10 t $ha^{-1}$ *fb* post emergence quizalofop p-ethyl @ 50 g $ha^{-1}$ at 25 DAS

$W_4$ - Post emergence imazethapyr @ 50 g $ha^{-1}$ at 15 DAS

$W_5$- Pre emergence diclosulam @ 12.5 g $ha^{-1}$ *fb* post emergence quizalofop p-ethyl @ 50 g $ha^{-1}$ at 25 DAS

$W_6$- Pre emergence diclosulam @ 12.5 g $ha^{-1}$ *fb* hand weeding at 25 DAS

$W_7$- Hand weeding at 20 and 40 DAS

$W_8$- No weeding (weedy check)

The crop was raised as per the POP recommendations of Kerala Agricultural University (KAU, 2016).

### 3.3.3 Preparatory Cultivation

For SSB the land was brought to fine tilth by ploughing with garden tiller. After removing the stubbles, field was levelled and 24 treatment plots were laid out with a gross plot size 3 m x 3 m. After laying out the plots, a pre sowing irrigation was given and left as such for 14 days to allow the weeds to germinate. After the elapse of 14 days emerged weeds were removed by light raking and individual bunds were made around each plot. A week after SSB preparation, land was prepared for normal seed bed and 24 treatment plots with a gross plot size of 3 m x 3 m were laid out, levelled and individual bunds were constructed around each plot.

**3.3.4 Lime Application**

Lime @ 250 kg ha$^{-1}$ was uniformly applied to the treatment plots at the time of ploughing.

**3.3.5 Manure and Fertilizer Application**

Farm yard manure (FYM) @ 20 t ha$^{-1}$ was uniformly applied to all plots. NPK was applied @ 20: 30: 10 kg ha$^{-1}$. Half N and full P and K were applied basally (before sowing the seeds) and remaining half N was applied at 20 DAS.

**3.3.6 Seeds and Sowing**

Seeds were dibbled at the rate of one seed per hill at a spacing of 30 cm x 15 cm on 8/06/2020. For uniform germination irrigation was given immediately after sowing.

**3.3.7 After Cultivation**

Germination count was recorded on 6 DAS, re-sowing was done in those places where seeds were not germinated.

**3.3.8 Plant Protection**

Mild incidence of maruca pod borer was noticed at 30 DAS and flowering stage. Coragen (chlorantraniliprole 18.5% SC) @ 3 ml 10 L$^{-1}$ was applied and a repeated spray was given 15 days after the first spray. Incidence of anthracnose was also noticed at 30 DAS and was controlled by spraying SAAF (carbendazim 12 % + mancozeb 12 % WP) @ 3 ml L$^{-1}$.

**3.3.9 Harvest**

The green tender pods were harvested once in three days from 43 to 80 DAS. A total number of 12 harvests were taken. Green pods were harvested from the observation plant and recorded the weight. Pod yield from the net plot area was also recorded.

3.4 OBSERVATION ON CROP

**3.4.1 Growth Parameters**

Excluding the border row plants, five plants were randomly tagged from each treatment for recording the observations on growth and yield parameters.

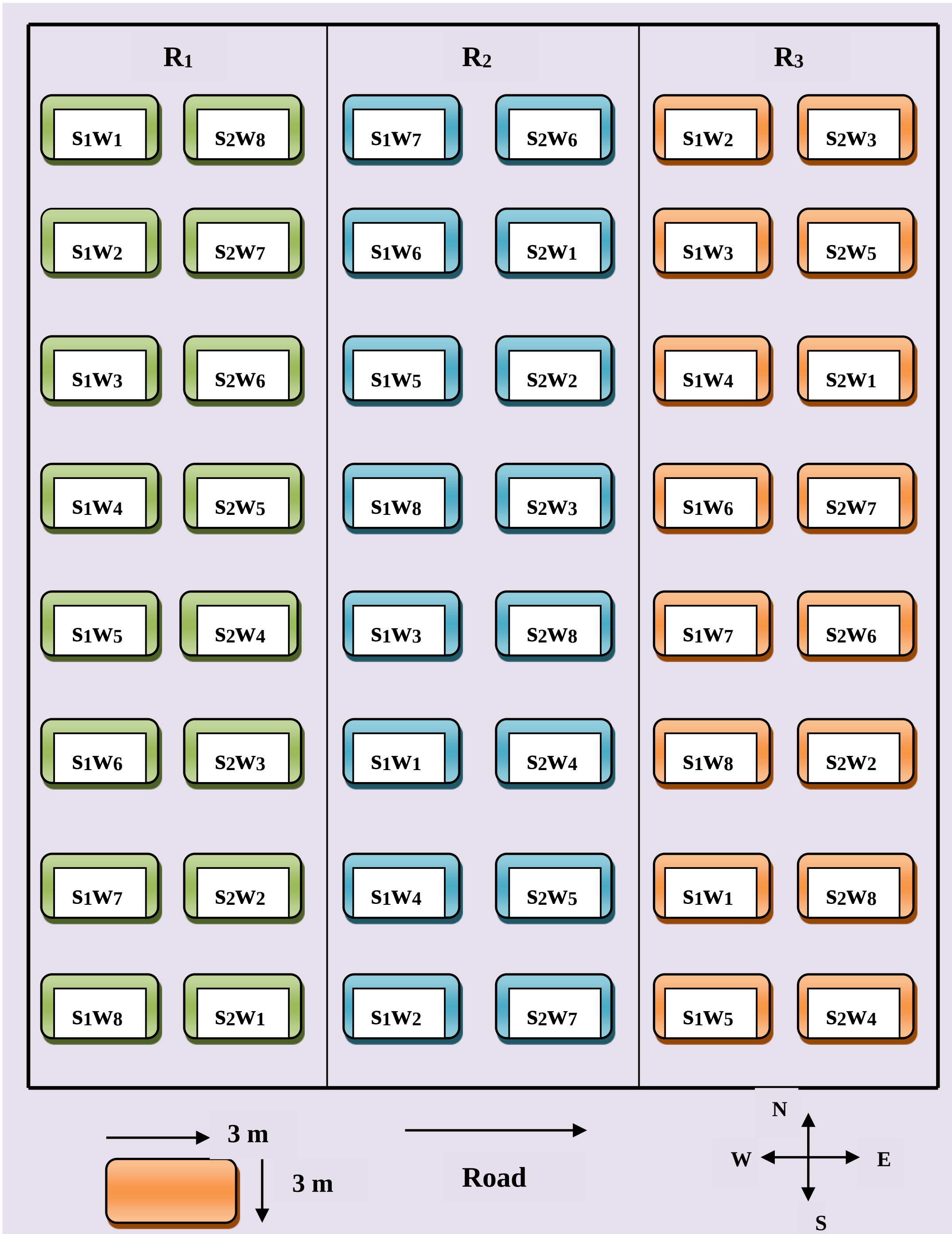


Fig 2.  Layout plan of the experimental field


Plate 1: General view of the experiment

***3.4.1.1 Phytotoxicity rating***

The treated plot was observed for visual symptoms of herbicide toxicity at 10 DAS. Based on the 0-10 scale rating was done on crop injury.

***3.4.1.2 Plant Height***

Plant height was measured from five tagged plants at 20, 40 and 60 DAS. It was measured from the ground level to the tip of the plant, average plant height was arrived and expressed in cm.

***3.4.1.3 Number of Leaves Per Plant***

Number of leaves in the tagged plants were also counted at 20, 40 and 60 DAS and the average were worked out.

***3.4.1.4 Number of Branches Per Plant***

From the observation plants, number of branches per plant were also recorded at 20, 40 and 60 DAS and the average were worked out.

***3.4.1.5 Dry Matter Production (DMP) Per Plant***

For recording the DMP at 20, 40 and 60 DAS, five plants were randomly selected and uprooted from outside the net plot area leaving border row. The plant samples were shade dried for two days in order to reduce the moisture content and then oven dried at 65 ± 5 °C till constant weight was attained. The average was worked out and expressed as g per plant.

**3.4.2 Physiological Parameters**

***3.4.2.1 Leaf Area Index (LAI)***

Leaf area index of trifoliate leaves was calculated by using linear method (length x breadth method) at 20, 40 and 60 DAS and expressed in $cm^2$.

$$\text{Leaf area} = L \times B \times K \times n$$

Where,

L = length of leaf (cm)

B = breadth of leaf (cm)

K (constant value) = 0.631 (Montgomery, 1911)

n = number of leaves

Then LAI was computed based on the recorded leaf area per plant by using the formula,

$$\text{LAI} = \frac{\text{Leaf area of plant (cm}^2\text{)}}{\text{Land area occupied by the plant (cm}^2\text{)}}$$

***3.4.2.2 Chlorophyll Content***

Chlorophyll content of the leaves was determined by the method suggested by Yoshida *et al*. (1976).

***3.4.2.3 Crop Growth Rate (CGR)***

Crop growth rate was calculated at two time intervals from 20 to 40 DAS and 40 to 60 DAS using the formula suggested by Watson (1958).

$$\text{CGR} = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{A} \quad \text{g m}^{-2}\ \text{day}^{-1}$$

Where $W_2$ and $W_1$ are the dry weight of the plant (g) at time $t_2$ and $t_1$ respectively

***3.4.2.4 Relative crop growth rate (RGR)***

Relative growth rate was also calculated at two time intervals from 20 to 40 DAS and from 40 to 60 DAS using the formula proposed by Evans (1972).

$$\text{RGR} = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{t_2 - t_1} \quad \text{mg g}^{-1}\ \text{day}^{-1}$$

Where $\log_e W_2$ and $\log_e W_1$ are the logarithmic value of dry weight of crop at two stages $n_2$ and $n_1$ respectively and $t_2$ and $t_1$ are duration in days between the crop growth stages.

**3.4.3 Nodule Parameters**

***3.4.3.1 Total Number of Nodules Per Plant***

Total number of nodules per plant was recorded at fifty percent flowering stage. Five plants were uprooted from outside the net plot area without causing any damage to the roots. Soil adhered to the roots were removed by dipping the roots in bucket filled with clean water. After the removal of soil, nodules from each plant was carefully removed and recorded the number and then the average was worked out and expressed as number per plant.

***3.4.3.2 Number2of2Effective Nodule Per Plant***

The separated nodules were observed for colour by cutting the nodules using a sharp blade. The nodules which appears pink color were identified as effective and recorded as effective nodules per plant. Nodules which appears green colour were considered as ineffective (Jordan, 1962).

***3.4.3.3 Nodule Fresh Weight***

Fresh weight of the nodules from each plant was recorded, average was worked out and expressed in g.

**3.4.4 Root Parameters**

Five plants uprooted for the determination of DMP were used for determining the root fresh weight and root volume.

***3.4.4.1 Root Fresh Weight***

Shoots and roots were separated from each uprooted plant, roots were once again washed in clean water and kept for half an hour to remove the water. The fresh weight of root was recorded for each plant separately and then the average was worked out and expressed in g at 20, 40 and 60 DAS.

***3.4.4.2 Root Volume***

Roots were dried in hot air oven at 65 ±°C to constant weight and root volume was determined by water displacement method at 20, 40 and 60 DAS.

**3.4.5 Yield Parameters and Yield**

Five plants in the net plot area were tagged as observation plants for recording the yield parameters.

***3.4.5.1 Days to 50 Per cent Flowering***

Days to 50 per cent flowering was recorded by counting the number of days taken from sowing to reach 50 per cent flowering in each treatment plot and expressed in days.

***3.4.5.2 Number of Pods Per Plant***

Green tender pods from the observation plants were counted at each harvest. Mean was worked out and expressed as number of pods per plant.

***3.4.5.3 Pod Length***

Five pods were randomly selected from the observation plant on each harvest for measuring the pod length from each treatment. Pod length was measured from base to the tip of the pod, the mean was calculated and expressed in cm.

***3.4.5.4 Pod Girth***

Five pods were randomly selected from the observation plant on each harvest for measuring the pod girth from each treatment. Pod girth was measured by using a thread and scale from the middle of the pod, mean was worked out and expressed in cm.

***3.4.5.5 Pod Weight***

Green tender pods harvested for recording the pod length and girth were used for recording the pod weight from each treatment, average weight was worked out and expressed in g.

***3.4.5.6 Green Pod Yield Per Plant***

Green tender pods from the observation plants were collected and weighed. Average was worked out to obtain the pod yield per plant and expressed in g.

***3.4.5.7 Total Green Pod Yield Per Hectare***

Green tender pods from each harvest from the net plot area of each treatment was weighed and recorded and expressed in kg ha$^{-1}$

***3.4.5.8 Haulm Yield Per Plant***

The observation plants were uprooted after harvesting the pods, sun dried and weighed individually and average was calculated and expressed as g per plant.

***3.4.4.9 Total Haulm Yield Per Hectare***

The plants were uprooted from the net plot area of each treatment after picking the pods, sun dried and weighed. On obtaining the haulm yield from net plot area total haulm yield ha$^{-1}$ was computed and expressed in kg ha$^{-1}$.

***3.4.4.10 Harvest Index***

The harvest index was worked out using the formula suggested by Donald and Hamblin (1976).

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

***3.4.4.11 Weed Index (WI)***

Weed index was worked out by the formula proposed by Gill and Vijayakumar (1969).

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

Where,

X= Yield from the treatment which recorded the minimum number of weeds

Y= Yield from the plot for which weed index is to be determined

**3.4. 6 Quality Parameter**

***3.4.6.1 Protein Content***

Protein content of pods was determined by the method proposed by Simpson *et al*. (1965) and expressed in percentage.

3.5 OBSERVATION ON WEEDS

**3.5.1 Weed Flora**

Weed species present in the experimental area were identified and recorded.

**3.5.2 Absolute Density (Ad)**

Absolute density was calculated by randomly placing the quadrant of size 0.25 m x 0.25 m at two places in each treatment plot and recording the number of weeds present with in the quadrant area. Weeds were grouped into grasses, BLW and sedges. Absolute density of grasses, sedges, BLW and total weed density were calculated at 15, 30 and 45 DAS using the formula proposed by Philips (1959).

$$Ad = \text{Total number of weeds of a given species in } m^2$$

### 3.5.3 Relative Density (Rd)

Relative density of grasses, sedges and BLW were calculated at 15, 30 and 45 DAS by using the formula suggested by Philips (1959).

$$Rd = \frac{\text{Absolute density of a species}}{\text{Total absolute density of all species}} \times 100$$

### 3.5.4 Weed Dry Weight

Weeds were uprooted from the same area where quadrant was placed for recording the absolute density of weeds at 15, 30 and 45 DAS from each treatment plot. Uprooted weeds were shade dried for two days and then dried in hot air oven at 65 ±ºC until constant weight was attained and expressed in g $m^{-2}$.

### 3.5.5 Weed Control Efficiency

Weed control efficiency was worked out by adopting the formula put forth by Mani and Gautham (1973).

$$WCE = \frac{WDWC - WDWT}{WDWC} \times 100$$

Where,

WCE - weed control efficiency

WDWC - weed dry weight in unweeded (control) plot

WDWT - weed dry weight in treated plot

3.6 CHEMICAL ANALYSIS

### 3.6.1 Soil Analysis

Composite soil sample was drawn from the experimental area prior to the start of the experiment for the analysis of soil physical and chemical properties and from each treatment after the harvest of crop for the analysis of N, P, K and organic carbon content.

***3.6.1.1 Organic Carbon***

For the estimation of soil organic carbon, soil was sieved through 0.2 mm sieve and analyzed by rapid titration method (Walkley and Black, 1934) and expressed in percentage.

***3.6.1.2 Available Nitrogen***

Alkaline potassium permanganate method (Subbiah and Asija, 1956) was adopted for the estimation of available N and expressed in kg $ha^{-1}$.

***3.6.1.3 Available Phosphorus***

Dickman and Brays molybdenum blue method (Jackson, 1973) was adopted for the determination of available phosphorous and expressed in kg $ha^{-1}$.

***3.6.1.4 Available Potassium***

Available potassium was determined by the procedure suggested by Jackson (1973) and expressed in kg $ha^{-1}$

**3.6.2 Plant Analysis**

Plant samples at harvest and weed samples at 30 and 45 DAS were analyzed for total N, P and K content. The plant and weed samples were shade dried for two days to reduce the moisture content and then oven dried at 65 ± 5 ºC. After drying, samples were powdered using a grinding machine. Accurately weighed samples were subjected to single acid digestion for the determination of N and di acid digestion for the determination of P and K.

***3.6.2.1 Total Nitrogen Content***

Modified microkjheldal method (Jackson, 1973) was used for the determination of total nitrogen content in plant and weeds.

***3.6.2.2 Total Phosphorus Content***

Vanadomolybdate phosphoric yellow color method (Jackson, 1973) was adopted for the determination of total phosphorus content in plant and weeds.

***3.6.2.3 Total Potassium Content***

Total potassium content of plant and weeds were determined by method suggested by Jackson (1973) using flame photometer.

***3.6.3 Uptake of Nutrients***

The total N, P and K uptake by crop and weeds were worked out by multiplying the nutrient content with the respective DMP. Total N, P and K uptake by crop was worked out by adding the respective haulm uptake and pod uptake and expressed in kg ha$^{-1}$.

3.7 SOIL ENZYME ASSAY

Enzyme assay was carried out at 15, 30 and 45 DAS. For analysis, soil samples were collected at 15 cm depth from each treatment and stored in polythene bag and analysis was completed within a week.

**3.7.1 Dehydrogenase Activity**

The dehydrogenase activity was determined by the method described by Casida *et al*. (1964) and expressed as µg triphenyl formazon (TPF) g$^{-1}$ soil day$^{-1}$.

**3.7.2 Urease Activity**

The urease activity was determined by the method suggested by Watts and Crisp (1954) and expressed as µg urea hydrolyzed g$^{-1}$ soil 4h$^{-1}$.

3.8 ECONOMIC ANALYSIS

Economic analysis was carried out to find out the net income, benefit cost ratio based on the prevailing market price of the inputs and produce.

**3.8.1 Net Income**

Net income was computed using the formula

Net income (₹ha$^{-1}$) = Gross income – cost of cultivation

**3.8.2 Benefit Cost Ratio (BCR)**

$$\text{BCR} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.9 PEST AND DISEASE INCIDENCE

During the crop period mild incidence of anthracnose and maruca pod borer were noticed at 30 DAS and at flowering stage. Recommended management practices were adopted to check the incidence below the economic threshold level.

## 3.10 STATISTICAL ANALYSIS

Analysis of Variance Technique for factorial randomized block design was adopted for the statistical analysis of the data and significance was tested using F test. Critical difference was calculated at 5 per cent probability level, wherever F values found significant. Appropriate transformations were done for those data which required transformation.

# RESULTS

# 4. RESULTS

Field experiment on "Integrated weed management in bush type vegetable cowpea (*Vigna unguiculata* subsp. *unguiculata* (L.) Verdcourt) was laid out during May 2019 to August 2019 at Coconut Research Station, Balaramapuram. The objective of the experiment was to find out a cost-effective eco-friendly weed management practice for bush type vegetable cowpea. The results obtained after the statistical analysis of data are presented in this chapter.

## 4.1 GROWTH PARAMETERS

### 4.1.1 Phytotoxicity Observation (Table 3 and 3a)

Phytotoxicity observation was done based on visual rating of 0-10 and observations were recorded at 10 days after herbicide application. Results revealed that none of the applied herbicides produced any phytotoxicity symptoms in bush type vegetable cowpea.

### 4.1.2 Plant Height (Table 3 and 3a)

Seed bed preparation significantly influenced the plant height at 20 and 40 DAS. Stale seed bed (SSB) registered the highest plant height of 32.4 and 62.0 cm, respectively as compared to normal seed bed which recorded a plant height of 31.3 and 60.4 cm, respectively at 20 and 40 DAS.

Weed management practices significantly influenced the plant height at 20 and 40 DAS. The highest plant height was recorded by treatment $W_2$ at 20 DAS and $W_1$ at 40 DAS and these treatments were statistically on par with all treatments except $W_5$, $W_6$ and $W_8$ at 20 DAS and $W_5$ and $W_8$ at 40 DAS.

The interaction effect was found non-significant at all the three stages of observation.

Table 3. Effect of seed bed preparation and weed management practices on plant height and phytotoxicity rating

| Treatments | Plant height (cm) | | | Phytotoxicity rating |
|---|---|---|---|---|
| | 20 DAS | 40 DAS | 60 DAS | 10 DAS |
| Seed bed preparation (S) | | | | |
| $S_1$ | 32.4 | 62.0 | 66.5 | 0.6 |
| $S_2$ | 31.3 | 60.4 | 65.2 | 0.6 |
| SE m (±) | 0.35 | 0.56 | 0.59 | - |
| CD (0.05) | 1.00 | 1.6 | NS | - |
| Weed management practices (W) | | | | |
| $W_1$ | 33.3 | 63.9 | 69.36 | 0 |
| $W_2$ | 33.4 | 60.8 | 65.92 | 1 |
| $W_3$ | 33.2 | 62.2 | 66.72 | 1 |
| $W_4$ | 31.7 | 60.6 | 65.40 | 1 |
| $W_5$ | 30.7 | 60.4 | 65.02 | 1 |
| $W_6$ | 30.0 | 61.5 | 63.98 | 1 |
| $W_7$ | 32.8 | 63.7 | 66.01 | 0 |
| $W_8$ | 29.7 | 57.4 | 64.86 | 0 |
| SE m (±) | 0.69 | 1.13 | 1.19 | - |
| CD (0.05) | 2.00 | 3.3 | NS | - |

NS: non-significant

Table 3a. Interaction effect of seed bed preparation and weed management practices on plant height and phytotoxicity ratting

| Treatments | Plant height (cm) | | | Phytotoxicity ratings |
|---|---|---|---|---|
| | 20 DAS | 40 DAS | 60 DAS | 10 DAS |
| $s_1w_1$ | 33.7 | 65.8 | 71.4 | 0 |
| $s_1w_2$ | 34.8 | 60.9 | 65.7 | 1 |
| $s_1w_3$ | 33.8 | 61.9 | 67.4 | 1 |
| $s_1w_4$ | 31.5 | 61.6 | 66.7 | 1 |
| $s_1w_5$ | 30.0 | 61.2 | 64.8 | 1 |
| $s_1w_6$ | 30.2 | 62.2 | 65.0 | 1 |
| $s_1w_7$ | 33.5 | 64.2 | 65.7 | 0 |
| $s_1w_8$ | 31.5 | 58.6 | 65.4 | 0 |
| $s_2w_1$ | 32.8 | 60.6 | 67.3 | 0 |
| $s_2w_2$ | 32.0 | 60.7 | 66.1 | 1 |
| $s_2w_3$ | 32.7 | 62.4 | 66.0 | 1 |
| $s_2w_4$ | 31.8 | 59.6 | 64.1 | 1 |
| $s_2w_5$ | 31.4 | 59.6 | 65.2 | 1 |
| $s_2w_6$ | 29.8 | 60.8 | 63.0 | 1 |
| $s_2w_7$ | 31.9 | 63.2 | 66.3 | 0 |
| $s_2w_8$ | 27.8 | 56.3 | 64.4 | 0 |
| SE m (±) | 0.98 | 1.16 | 1.67 | - |
| CD (0.05) | NS | NS | NS | - |

NS: non-significant

### 4.1.3 Number of Leaves Per Plant (Table 4 and 4a)

Seed bed preparation had significant effect on the number of leaves per plant at 20 and 60 DAS but it had no significant impact at 40 DAS. Stale seed bed recorded 7.38 and 18.33 number of leaves per plant at 20 and 60 DAS, respectively and it was significantly higher compared to normal seed bed.

Weed management practices also had a favouable influence on number of leaves per plant. At 20 DAS, $W_1$ recorded higher number of leaves (7.83 per plant) and was on par with $W_3$, $W_2$, $W_4$ and $W_6$. At 40 DAS, $W_3$ recorded higher number of leaves per plant (15.50) and was statistically comparable with $W_2$ and $W_5$. At 60 DAS, $W_2$ and $W_6$ recorded higher number of leaves per plant (19.83) and were significantly higher compared to other treatments. At all the three stages of observation, weedy check ($W_8$) recorded significantly lower number of leaves per plant.

Interaction effect was significant only at 60 DAS and the treatment combination $s_1w_6$ recorded the highest number of leaves per plant and was on par with $s_1w_2$.

### 4.1.4 Number of Branches Per Plant (Table 5 and 5a)

Number of branches per plant at 40 and 60 DAS was significantly influenced by seed bed preparation. At both stages, SSB recorded same number of branches per plant (3.17) and was significantly higher compared to normal seed bed.

Weed management practices had significant effect on number of branches per plant at 20 DAS and $W_3$ recorded higher number of branches per plant (2.50) and was on par with $W_1$, $W_2$ and $W_6$. However, at 40 and 60 DAS, weed management practices had no influence on number of branches per plant.

Interaction effect was not significant at all the three stages of observation.

Table 4. Effect of seed bed preparation and weed management practices on number of leaves per plant

| Treatments | Number of leaves per plant | | |
|---|---|---|---|
| | 20 DAS | 40 DAS | 60 DAS |
| Seed bed preparation (S) | | | |
| $S_1$ | 7.38 | 13.96 | 18.33 |
| $S_2$ | 6.29 | 14.04 | 17.00 |
| SE m (±) | 0.19 | 0.19 | 0.26 |
| CD (0.05) | 0.56 | NS | 0.74 |
| Weed management practices (W) | | | |
| $W_1$ | 7.83 | 14.17 | 18.33 |
| $W_2$ | 7.33 | 15.33 | 19.83 |
| $W_3$ | 7.67 | 15.50 | 17.83 |
| $W_4$ | 7.17 | 13.83 | 17.83 |
| $W_5$ | 6.33 | 14.67 | 17.50 |
| $W_6$ | 6.83 | 14.33 | 19.83 |
| $W_7$ | 5.83 | 12.67 | 17.50 |
| $W_8$ | 5.67 | 11.50 | 15.17 |
| SE m (±) | 0.39 | 0.38 | 0.51 |
| CD (0.05) | 1.12 | 1.11 | 1.48 |

NS: non-significant

Table 4a. Interaction effect of seed bed preparation and weed management practices on number of leaves per plant

| Treatments | Number of leaves per plant | | |
|---|---|---|---|
| | 20 DAS | 40 DAS | 60 DAS |
| $s_1w_1$ | 9.00 | 14.33 | 18.67 |
| $s_1w_2$ | 8.33 | 15.00 | 20.67 |
| $s_1w_3$ | 8.00 | 15.67 | 18.67 |
| $s_1w_4$ | 7.33 | 14.00 | 18.67 |
| $s_1w_5$ | 6.00 | 13.67 | 18.00 |
| $s_1w_6$ | 7.67 | 14.67 | 22.67 |
| $s_1w_7$ | 6.33 | 12.67 | 16.67 |
| $s_1w_8$ | 7.00 | 11.67 | 16.67 |
| $s_2w_1$ | 6.67 | 14.00 | 18.00 |
| $s_2w_2$ | 7.33 | 15.67 | 19.00 |
| $s_2w_3$ | 6.67 | 15.33 | 17.00 |
| $s_2w_4$ | 6.33 | 13.67 | 16.00 |
| $s_2w_5$ | 6.67 | 15.67 | 17.00 |
| $s_2w_6$ | 6.00 | 14.00 | 17.00 |
| $s_2w_7$ | 5.33 | 12.67 | 18.33 |
| $s_2w_8$ | 5.00 | 11.33 | 13.67 |
| SE m (±) | 0.55 | 0.54 | 0.72 |
| CD (0.05) | NS | NS | 2.09 |

NS: non-significant

Table 5. Effect of seed bed preparation and weed management practices on number of branches per plant

| Treatments | Number of branches per plant | | |
|---|---|---|---|
| | 20 DAS | 40 DAS | 60 DAS |
| Seed bed preparation (S) | | | |
| $S_1$ | 2.17 | 3.17 | 3.17 |
| $S_2$ | 2.00 | 2.92 | 2.92 |
| SE m (±) | 0.07 | 0.07 | 0.07 |
| CD (0.05) | NS | 0.21 | 0.21 |
| Weed management practices (W) | | | |
| $W_1$ | 2.33 | 3.00 | 3.00 |
| $W_2$ | 2.17 | 3.17 | 3.17 |
| $W_3$ | 2.50 | 3.17 | 3.17 |
| $W_4$ | 2.00 | 3.17 | 3.17 |
| $W_5$ | 2.00 | 3.00 | 3.00 |
| $W_6$ | 2.17 | 3.00 | 3.00 |
| $W_7$ | 2.00 | 3.00 | 3.00 |
| $W_8$ | 1.50 | 2.83 | 2.83 |
| SE m (±) | 0.15 | 0.14 | 0.14 |
| CD (0.05) | 0.43 | NS | NS |

NS: non-significant

Table 5a. Interaction effect of seed bed preparation and weed management practices on number of branches per plant

| Treatments | Number of branches per plant | | |
|---|---|---|---|
| | 20 DAS | 40 DAS | 60 DAS |
| $s_1w_1$ | 2.33 | 3.00 | 3.00 |
| $s_1w_2$ | 2.33 | 3.33 | 3.33 |
| $s_1w_3$ | 3.00 | 3.33 | 3.33 |
| $s_1w_4$ | 2.00 | 3.33 | 3.33 |
| $s_1w_5$ | 2.00 | 3.00 | 3.00 |
| $s_1w_6$ | 2.00 | 3.00 | 3.00 |
| $s_1w_7$ | 2.00 | 3.33 | 3.33 |
| $s_1w_8$ | 1.67 | 3.00 | 3.00 |
| $s_2w_1$ | 2.33 | 3.00 | 3.00 |
| $s_2w_2$ | 2.00 | 3.00 | 3.00 |
| $s_2w_3$ | 2.00 | 3.00 | 3.00 |
| $s_2w_4$ | 2.00 | 3.00 | 3.00 |
| $s_2w_5$ | 2.00 | 3.00 | 3.00 |
| $s_2w_6$ | 2.33 | 3.00 | 3.00 |
| $s_2w_7$ | 2.00 | 2.67 | 2.67 |
| $s_2w_8$ | 1.33 | 2.67 | 2.67 |
| SE m (±) | 0.21 | 0.20 | 0.20 |
| CD (0.05) | NS | NS | NS |

NS: non-significant

### 4.1.5 Dry Matter Production (DMP) Per Plant (Table 6 and 6a)

Dry matter production per plant at three stages of observation (20, 40 and 60 DAS) was significantly influenced by seed bed preparation. Stale seed bed was found superior and recorded the highest plant dry weight of 7.87, 24.09 and 50.57 g per plant, respectively at 20, 40 and 60 DAS compared to normal seed bed.

Data on weed management practices revealed that at 20 DAS, $W_6$ recorded the highest DMP (8.36 g per plant) and it was statistically on par with $W_4$, $W_3$ and $W_2$. However, at 40 and 60 DAS, $W_3$ recorded the highest DMP (24.59 and 51.51 g per plant, respectively) and it was statistically comparable with all weed management treatments except $W_1$, $W_4$, $W_5$ and $W_8$ at 40 DAS and $W_4$ and $W_8$ at 60 DAS.

Interaction effect did not have any significant influence on DMP.

## 4.2 PHYSIOLOGICAL PARAMETERS

### 4.2.1 Leaf Area Index (LAI) (Table 9 and 9a)

Seed bed preparation had significant impact on LAI at 20, 40 and 60 DAS. Stale seed bed recorded LAI of 0.37, 2.37 and 3.11, respectively at 20, 40 and 60 DAS which was significantly higher compared to normal seed bed (0.28, 2.13 and 2.22, respectively).

Perusal of data on weed management practices revealed that at 20 DAS, $W_1$ recorded higher LAI (0.42) which was statistically at par with $W_2$ and $W_3$. At 40 DAS, $W_3$ recorded higher LAI which was on par with other treatments except $W_4$, $W_7$ and $W_8$ and at 60 DAS, $W_2$ recorded higher LAI which was statistically on par with $W_1$. Weedy check ($W_8$) recorded the lowest leaf area index at all the three stages of observation.

Interaction effect was significant only at 20 and 60 DAS. At 20 DAS, the treatment combinations $s_1w_1$ and $s_1w_2$ recorded the highest LAI which was statistically on par with $s_1w_3$. At 60 DAS, $s_1w_2$ recorded the highest LAI which was on par with $s_1w_6$.

Table 6. Effect of seed bed preparation and weed management practices on dry matter production (DMP) per plant

| Treatments | DMP (g per plant) | | |
|---|---|---|---|
| | 20 DAS | 40 DAS | 60 DAS |
| Seed bed preparation (S) | | | |
| $S_1$ | 7.87 | 24.09 | 50.57 |
| $S_2$ | 7.04 | 22.05 | 46.95 |
| SE m (±) | 0.11 | 0.26 | 0.52 |
| CD (0.05) | 0.31 | 0.74 | 1.52 |
| Weed management practices (W) | | | |
| $W_1$ | 7.17 | 22.82 | 48.67 |
| $W_2$ | 7.83 | 23.16 | 49.69 |
| $W_3$ | 7.89 | 24.59 | 51.51 |
| $W_4$ | 8.09 | 22.80 | 45.80 |
| $W_5$ | 6.58 | 23.01 | 50.25 |
| $W_6$ | 8.36 | 24.00 | 50.55 |
| $W_7$ | 7.41 | 23.56 | 50.09 |
| $W_8$ | 6.31 | 20.62 | 43.50 |
| SE m (±) | 0.21 | 0.51 | 1.05 |
| CD (0.05) | 0.62 | 1.49 | 3.04 |

Table 6a. Interaction effect of seed bed preparation and weed management practices on dry matter production (DMP) per plant

| Treatments | DMP (g per plant) | | |
|---|---|---|---|
| | 20 DAS | 40 DAS | 60 DAS |
| $s_1w_1$ | 7.92 | 24.10 | 49.94 |
| $s_1w_2$ | 7.93 | 24.65 | 53.57 |
| $s_1w_3$ | 8.57 | 25.97 | 53.75 |
| $s_1w_4$ | 8.49 | 23.43 | 46.45 |
| $s_1w_5$ | 7.01 | 24.17 | 52.91 |
| $s_1w_6$ | 8.71 | 24.41 | 51.83 |
| $s_1w_7$ | 7.65 | 24.75 | 51.45 |
| $s_1w_8$ | 6.68 | 21.24 | 44.62 |
| $s_2w_1$ | 6.41 | 21.54 | 47.40 |
| $s_2w_2$ | 7.72 | 21.67 | 45.80 |
| $s_2w_3$ | 7.21 | 23.21 | 49.27 |
| $s_2w_4$ | 7.70 | 23.21 | 45.15 |
| $s_2w_5$ | 6.14 | 21.85 | 47.58 |
| $s_2w_6$ | 8.03 | 23.60 | 49.27 |
| $s_2w_7$ | 7.17 | 22.37 | 48.73 |
| $s_2w_8$ | 5.94 | 20.00 | 42.38 |
| SE m (±) | 0.30 | 0.73 | 1.48 |
| CD (0.05) | NS | NS | NS |

NS: non-significant

Table 7. Effect of seed bed preparation and weed management practices on LAI

| Treatments | LAI | | |
|---|---|---|---|
| | 20 DAS | 40 DAS | 60 DAS |
| Seed bed preparation (S) | | | |
| $S_1$ | 0.37 | 2.37 | 3.11 |
| $S_2$ | 0.28 | 2.13 | 2.22 |
| SE m (±) | 0.01 | 0.05 | 0.03 |
| CD (0.05) | 0.03 | 0.15 | 0.10 |
| Weed management practices (W) | | | |
| $W_1$ | 0.42 | 2.50 | 2.99 |
| $W_2$ | 0.40 | 2.51 | 3.17 |
| $W_3$ | 0.38 | 2.57 | 2.85 |
| $W_4$ | 0.31 | 2.03 | 2.32 |
| $W_5$ | 0.28 | 2.36 | 2.65 |
| $W_6$ | 0.35 | 2.38 | 2.91 |
| $W_7$ | 0.25 | 2.17 | 2.62 |
| $W_8$ | 0.21 | 1.49 | 1.83 |
| SE m (±) | 0.02 | 0.10 | 0.07 |
| CD (0.05) | 0.05 | 0.29 | 0.20 |

Table 7a. Interaction effect of seed bed preparation and weed management practices on LAI

| Treatments | LAI | | |
|---|---|---|---|
| | 20 DAS | 40 DAS | 60 DAS |
| $s_1w_1$ | 0.50 | 2.55 | 3.38 |
| $s_1w_2$ | 0.50 | 2.65 | 3.76 |
| $s_1w_3$ | 0.44 | 2.71 | 3.33 |
| $s_1w_4$ | 0.34 | 2.22 | 2.66 |
| $s_1w_5$ | 0.25 | 2.40 | 2.98 |
| $s_1w_6$ | 0.41 | 2.57 | 3.59 |
| $s_1w_7$ | 0.28 | 2.27 | 2.94 |
| $s_1w_8$ | 0.24 | 1.61 | 2.26 |
| $s_2w_1$ | 0.34 | 2.45 | 2.61 |
| $s_2w_2$ | 0.30 | 2.37 | 2.58 |
| $s_2w_3$ | 0.32 | 2.43 | 2.37 |
| $s_2w_4$ | 0.28 | 1.84 | 1.98 |
| $s_2w_5$ | 0.31 | 2.32 | 2.31 |
| $s_2w_6$ | 0.29 | 2.18 | 2.22 |
| $s_2w_7$ | 0.23 | 2.07 | 2.30 |
| $s_2w_8$ | 0.19 | 1.37 | 1.41 |
| SE m (±) | 0.03 | 0.14 | 0.10 |
| CD (0.05) | 0.08 | NS | 0.28 |

NS: non-significant

### 4.2.3 Chlorophyll Content (Table 8, 8a, 9 and 9a)

Seed bed preparation had no significant effect on chlorophyll a, chlorophyll b and total chlorophyll at 40 DAS, however it had significant effect on chlorophyll a and total chlorophyll at 60 DAS. Stale seed bed recorded higher chlorophyll a and total chlorophyll content of 1.075 mg $g^{-1}$ and 2.097 mg $g^{-1}$, respectively at 60 DAS.

Weed management practices had significant effect on chlorophyll a, b and total chlorophyll at both 40 and 60 DAS. The treatment $W_3$ recorded significantly higher chlorophyll a, chlorophyll b and total chlorophyll (1.480, 1.382 and 2.862 mg $g^{-1}$, respectively) at 40 DAS. However, at 60 DAS, $W_2$ recorded the highest chlorophyll a content and total chlorophyll content (1.134 and 2.152 mg $g^{-1}$) and $W_7$ recorded the highest chlorophyll b content (1.029 mg $g^{-1}$).

Interaction effect had significant impact on chlorophyll a, chlorophyll b and total chlorophyll content at 40 and 60 DAS. The treatment combination $s_2w_3$ recorded the highest chlorophyll a content and was comparable with $s_1w_6$ at 40 DAS. However, at 60 DAS, $s_1w_2$ recorded the highest chlorophyll a content which was on par with $s_1w_3$. With respect to chlorophyll b content, the treatment combination $s_2w_3$ recorded the highest chlorophyll b content which was on par with $s_1w_6$ at 40 DAS and at 60 DAS $s_2w_6$ recorded the highest chlorophyll b content which was statistically comparable with $s_1w_7$, $s_2w_7$, $s_1w_1$ and $s_1w_8$. The total chlorophyll content was found to be the highest in $s_2w_3$ at 40 DAS, which was significantly superior to other treatments. At 60 DAS, $s_1w_2$ recorded the highest total chlorophyll content which was statistically comparable with $s_1w_3$.

### 4.2.4 Crop Growth Rate (CGR) (Table 10 and 10 a)

Seed bed preparation had significant effect on CGR at two intervals (20 to 40 DAS and 40 to 60 DAS). Stale seed bed recorded significantly higher CGR of 18.02 and 29.42 g $m^{-2}$ $day^{-1}$ at 20 to 40 DAS and 40 to 60 DAS, respectively.

Weed management practices had a favourable effect on CGR at two different intervals of observation. At 20 to 40 DAS, $W_3$ recorded higher CGR (18.55 g $m^{-2}$ $day^{-1}$)

which was statistically comparable with $W_5$ and $W_7$ and at 40 to 60 DAS time interval $W_5$ recorded higher CGR (30.27 g $m^{-2}$ $day^{-1}$) which was statistically on par with all treatments except $W_1$, $W_4$ and $W_8$. Weedy check ($W_8$) recorded the lowest CGR at 20 to 40 DAS and 40 to 60 DAS.

Interaction effect had no significant influence on CGR.

**4.2.4 Relative Growth Rate (RGR) (Table 10 and 10a)**

Seed bed preparation had no significant effect on RGR at 20 to 40 DAS and 40 to 60 DAS.

Relative growth rate was favourably influenced by weed management practices. The treatment $W_5$ recorded the highest RGR (62.78 and 39.09 mg $g^{-1}$ $day^{-1}$) both at 20 to 40 DAS and 40 to 60 DAS. However, it was significantly superior to all other treatments at 20 to 40 DAS and at 40 to 60 DAS it was on par with rest of the treatments except $W_4$.

Interaction did not have any significant effect on RGR at both the time intervals

4.3 NODULE PARAMETERS

**4.3.1 Total Number of Nodules Per Plant (Table 11 and 11 a)**

Stale seed bed recorded significantly higher number of total nodules (12.00 per plant) as compared to normal seed bed (9.50 per plant).

Perusal of data on weed management practices observed that $W_6$ recorded significantly higher number of total nodules per plant (17.50). The treatment $W_6$ was followed by $W_3$ and these two treatments were significantly superior to other treatments. The lowest number of total nodules per plant was observed in $W_8$ (7.00).

Interaction effect revealed that the treatment combination $s_1w_6$ recorded significantly higher number of total nodules per plant (20.33) and the lowest was recorded in $s_2w_8$ (5.68).

**4.4.2 Effective Number of Nodules Per Plant (Table 11 and 11a)**

Effective number of nodules per plant was also influenced by seed bed preparation. Stale seed bed noted significantly higher number of effective nodules per plant (7.08).

Effective number of nodules per plant was also significantly influenced by weed management practices. The result followed the same trend as that of total number of nodules per plant. Among the weed management practices $W_6$ recorded the highest number of effective nodules (10.50 per plant) and the lowest was recorded in weedy check (1.67 per plant).

Interaction effect had positive influence on number of effective nodules and the treatment combination $s_1w_6$ recorded the highest number of effective nodules per plant (12.67) which was statistically comparable with $s_1w_5$ (11.33).

**4.3.3 Nodule Fresh Weight Per Plant (Table 11 and 11a)**

Seed bed manipulation had significant influence on nodule fresh weight per plant. Nodule fresh weight per plant was significantly higher in SSB (0.833 g) as against the nodule fresh weight per plant of 0.646 g in normal seed bed.

Nodule fresh weight per plant was also favourably influenced by weed management practices. The treatment $W_3$ recorded the highest nodule fresh weight per plant (1.27 g) which was statistically on a line with $W_6$. Weedy check ($W_8$) recorded the lowest nodule fresh weight per plant (0.26 g).

Nodule fresh weight per plant was also significantly influenced by the interaction between seed bed preparation and weed management practice. The treatment combination, $s_1w_3$ recorded the highest nodule fresh weight per plant (1.62 g) which was significantly superior compared to other treatment combinations. The nodule fresh weight per plant was the lowest in the treatment combination $s_2w_8$ (0.27 g).

Table 8. Effect of seed bed preparation and weed management practices on chlorophyll content at 40 DAS

| Treatments | Chlorophyll a (mg $g^{-1}$) | Chlorophyll b (mg $g^{-1}$) | Total Chlorophyll (mg $g^{-1}$) |
|---|---|---|---|
| Seed bed preparation (S) | | | |
| $S_1$ | 1.350 | 1.276 | 2.626 |
| $S_2$ | 1.352 | 1.279 | 2.631 |
| SE m (±) | 0.006 | 0.010 | 0.010 |
| CD (0.05) | NS | NS | NS |
| Weed management practices (W) | | | |
| $W_1$ | 1.319 | 1.258 | 2.577 |
| $W_2$ | 1.400 | 1.290 | 2.690 |
| $W_3$ | 1.480 | 1.382 | 2.862 |
| $W_4$ | 1.326 | 1.234 | 2.560 |
| $W_5$ | 1.301 | 1.280 | 2.580 |
| $W_6$ | 1.426 | 1.312 | 2.739 |
| $W_7$ | 1.281 | 1.237 | 2.518 |
| $W_8$ | 1.277 | 1.228 | 2.505 |
| SE m (±) | 0.012 | 0.021 | 0.020 |
| CD (0.05) | 0.033 | 0.060 | 0.058 |

NS: non-significant

Table 8a. Interaction effect of seed bed preparation and weed management practices on chlorophyll content at 40 DAS

| Treatments | Chlorophyll a (mg $g^{-1}$) | Chlorophyll b (mg $g^{-1}$) | Total Chlorophyll (mg $g^{-1}$) |
|---|---|---|---|
| $s_1w_1$ | 1.313 | 1.274 | 2.587 |
| $s_1w_2$ | 1.421 | 1.291 | 2.712 |
| $s_1w_3$ | 1.411 | 1.336 | 2.747 |
| $s_1w_4$ | 1.245 | 1.159 | 2.404 |
| $s_1w_5$ | 1.304 | 1.284 | 2.588 |
| $s_1w_6$ | 1.527 | 1.383 | 2.910 |
| $s_1w_7$ | 1.279 | 1.223 | 2.501 |
| $s_1w_8$ | 1.380 | 1.288 | 2.561 |
| $s_2w_1$ | 1.325 | 1.242 | 2.567 |
| $s_2w_2$ | 1.380 | 1.288 | 2.668 |
| $s_2w_3$ | 1.548 | 1.429 | 2.977 |
| $s_2w_4$ | 1.408 | 1.309 | 2.717 |
| $s_2w_5$ | 1.297 | 1.275 | 2.572 |
| $s_2w_6$ | 1.325 | 1.241 | 2.567 |
| $s_2w_7$ | 1.282 | 1.252 | 2.534 |
| $s_2w_8$ | 1.250 | 1.198 | 2.448 |
| SE m (±) | 0.016 | 0.029 | 0.028 |
| CD (0.05) | 0.047 | 0.085 | 0.082 |

Table 9. Effect of seed bed preparation and weed management practice on chlorophyll content at 60 DAS

| Treatments | Chlorophyll a (mg $g^{-1}$) | Chlorophyll b (mg $g^{-1}$) | Total Chlorophyll (mg $g^{-1}$) |
|---|---|---|---|
| Seed bed preparation (S) | | | |
| $S_1$ | 1.075 | 1.021 | 2.097 |
| $S_2$ | 1.028 | 1.021 | 2.049 |
| SE m (±) | 0.001 | 0.001 | 0.001 |
| CD (0.05) | 0.002 | NS | 0.003 |
| Weed management practices (W) | | | |
| $W_1$ | 1.037 | 1.018 | 2.055 |
| $W_2$ | 1.134 | 1.018 | 2.152 |
| $W_3$ | 1.114 | 1.020 | 2.134 |
| $W_4$ | 1.034 | 1.018 | 2.052 |
| $W_5$ | 1.027 | 1.020 | 2.048 |
| $W_6$ | 1.025 | 1.027 | 2.052 |
| $W_7$ | 1.017 | 1.029 | 2.046 |
| $W_8$ | 1.025 | 1.019 | 2.045 |
| SE m (±) | 0.001 | 0.003 | 0.002 |
| CD (0.05) | 0.003 | 0.007 | 0.006 |

NS: non-significant

Table 9a. Interaction effect of seed bed preparation and weed management practices on chlorophyll content at 60 DAS

| Treatments | Chlorophyll a (mg $g^{-1}$) | Chlorophyll b (mg $g^{-1}$) | Total Chlorophyll (mg $g^{-1}$) |
|---|---|---|---|
| $s_1w_1$ | 1.035 | 1.025 | 2.060 |
| $s_1w_2$ | 1.216 | 1.018 | 2.234 |
| $s_1w_3$ | 1.215 | 1.015 | 2.230 |
| $s_1w_4$ | 1.039 | 1.015 | 2.054 |
| $s_1w_5$ | 1.025 | 1.022 | 2.048 |
| $s_1w_6$ | 1.029 | 1.022 | 2.051 |
| $s_1w_7$ | 1.018 | 1.031 | 2.050 |
| $s_1w_8$ | 1.025 | 1.024 | 2.048 |
| $s_2w_1$ | 1.038 | 1.012 | 2.050 |
| $s_2w_2$ | 1.053 | 1.018 | 2.071 |
| $s_2w_3$ | 1.013 | 1.024 | 2.038 |
| $s_2w_4$ | 1.030 | 1.021 | 2.051 |
| $s_2w_5$ | 1.029 | 1.019 | 2.047 |
| $s_2w_6$ | 1.020 | 1.033 | 2.053 |
| $s_2w_7$ | 1.016 | 1.027 | 2.043 |
| $s_2w_8$ | 1.026 | 1.015 | 2.041 |
| SE m (±) | 0.001 | 0.004 | 0.003 |
| CD (0.05) | 0.004 | 0.010 | 0.009 |

Table 10. Effect of seed bed preparation and weed management practices on CGR and RGR

| Treatments | CGR (g $m^{-2}$ $day^{-1}$) | | RGR (mg $g^{-1}$ $day^{-1}$) | |
|---|---|---|---|---|
| | 20-40 DAS | 40-60 DAS | 20-40 DAS | 40-60 DAS |
| Seed bed preparation (S) | | | | |
| $S_1$ | 18.02 | 29.42 | 56.11 | 37.05 |
| $S_2$ | 16.67 | 27.42 | 57.62 | 37.81 |
| SE m (±) | 0.19 | 0.30 | 0.64 | 0.35 |
| CD (0.05) | 0.55 | 0.88 | NS | NS |
| Weed management practices (W) | | | | |
| $W_1$ | 17.39 | 27.72 | 58.14 | 37.94 |
| $W_2$ | 17.04 | 29.47 | 54.17 | 37.75 |
| $W_3$ | 18.55 | 29.21 | 56.98 | 37.02 |
| $W_4$ | 16.34 | 25.56 | 51.93 | 35.29 |
| $W_5$ | 18.25 | 30.27 | 62.78 | 39.09 |
| $W_6$ | 17.37 | 29.49 | 53.75 | 37.23 |
| $W_7$ | 17.94 | 29.49 | 57.89 | 37.77 |
| $W_8$ | 15.90 | 25.43 | 59.31 | 37.34 |
| SE m (±) | 0.38 | 0.61 | 1.28 | 0.69 |
| CD (0.05) | 1.11 | 1.76 | 3.71 | 2.01 |

NS: non-significant

Table10a. Interaction effect of seed bed preparation and weed management practices on CGR and RGR

| Treatments | CGR (g $m^{-2}$ $day^{-1}$) | | RGR (mg $g^{-1}$ $day^{-1}$) | |
|---|---|---|---|---|
| | 20 to 40 DAS | 40 to 60 DAS | 20 to 40 DAS | 40 to 60 DAS |
| $s_1w_1$ | 17.97 | 28.71 | 55.65 | 36.44 |
| $s_1w_2$ | 18.58 | 32.13 | 56.71 | 38.80 |
| $s_1w_3$ | 19.33 | 30.86 | 55.53 | 36.37 |
| $s_1w_4$ | 16.61 | 25.58 | 50.86 | 34.23 |
| $s_1w_5$ | 19.06 | 31.93 | 61.95 | 39.17 |
| $s_1w_6$ | 17.44 | 30.46 | 51.53 | 37.74 |
| $s_1w_7$ | 18.99 | 29.68 | 58.74 | 36.60 |
| $s_1w_8$ | 16.17 | 25.98 | 57.87 | 37.12 |
| $s_2w_1$ | 16.81 | 26.72 | 60.63 | 39.43 |
| $s_2w_2$ | 15.50 | 26.81 | 51.62 | 36.69 |
| $s_2w_3$ | 17.76 | 28.96 | 58.42 | 37.67 |
| $s_2w_4$ | 16.07 | 25.54 | 52.99 | 36.34 |
| $s_2w_5$ | 17.44 | 28.60 | 63.60 | 39.00 |
| $s_2w_6$ | 17.33 | 28.52 | 55.98 | 36.81 |
| $s_2w_7$ | 16.80 | 29.29 | 57.04 | 38.94 |
| $s_2w_8$ | 15.61 | 24.87 | 60.74 | 37.56 |
| SE m (±) | 0.54 | 0.86 | 1.81 | 0.98 |
| CD (0.05) | NS | NS | NS | NS |

NS: non-significant

Table 11. Effect of seed bed preparation and weed management practices on nodule parameters at 50 per cent flowering stage

| Treatments | Total nodules (no. per plant) | Effective nodules (no. per plant) | Nodule fresh weight (g) |
|---|---|---|---|
| Seed bed preparation (S) | | | |
| $S_1$ | 12.00 | 7.08 | 0.833 |
| $S_2$ | 9.50 | 4.75 | 0.646 |
| SE m (±) | 0.23 | 0.16 | 0.02 |
| CD (0.05) | 0.67 | 0.47 | 0.05 |
| Weed management practices (W) | | | |
| $W_1$ | 8.50 | 4.17 | 0.60 |
| $W_2$ | 8.00 | 3.33 | 0.72 |
| $W_3$ | 12.83 | 7.83 | 1.27 |
| $W_4$ | 9.17 | 5.83 | 0.52 |
| $W_5$ | 13.17 | 7.33 | 0.84 |
| $W_6$ | 17.50 | 10.50 | 1.22 |
| $W_7$ | 9.83 | 6.67 | 0.50 |
| $W_8$ | 7.00 | 1.67 | 0.26 |
| SE m (±) | 0.46 | 0.46 | 0.03 |
| CD (0.05) | 1.34 | 1.34 | 0.09 |

Table 11a. Interaction effect of seed bed preparation and weed management practices on nodule parameters at 50 per cent flowering stage

| Treatments | Total nodules (no. per plant) | Effective nodules (no. per plant) | Nodule fresh weight (g) |
|---|---|---|---|
| $s_1w_1$ | 8.33 | 4.67 | 0.76 |
| $s_1w_2$ | 6.67 | 2.67 | 0.97 |
| $s_1w_3$ | 12.00 | 8.67 | 1.62 |
| $s_1w_4$ | 9.00 | 5.67 | 0.68 |
| $s_1w_5$ | 18.67 | 11.33 | 0.63 |
| $s_1w_6$ | 20.33 | 12.67 | 1.34 |
| $s_1w_7$ | 12.67 | 9.00 | 0.41 |
| $s_1w_8$ | 8.33 | 2.00 | 0.25 |
| $s_2w_1$ | 8.67 | 3.67 | 0.43 |
| $s_2w_2$ | 9.33 | 4.00 | 0.47 |
| $s_2w_3$ | 13.67 | 7.00 | 0.91 |
| $s_2w_4$ | 9.33 | 6.00 | 0.35 |
| $s_2w_5$ | 7.67 | 3.33 | 1.05 |
| $s_2w_6$ | 14.67 | 8.33 | 1.10 |
| $s_2w_7$ | 7.00 | 4.33 | 0.59 |
| $s_2w_8$ | 5.67 | 1.33 | 0.27 |
| SE m (±) | 0.651 | 0.46 | 0.05 |
| CD (0.05) | 1.89 | 1.34 | 0.13 |

## 4.4 ROOT PARAMETERS

### 4.4.1 Root Fresh Weight (Table 12 and 12a)

Root fresh weight was significantly influenced by seed bed preparation at 20 and 60 DAS. Stale seed bed method recorded the highest root fresh weight of 6.73 g and 19.49 g at 20 and 60 DAS, respectively and was significantly superior to normal seed bed.

Among the weed management practices, $W_8$ (weedy check) recorded the lowest root fresh weight (5.12 g) at all three stages and $W_3$ recorded the highest root fresh weight of 7.09, 10.96 and 21.89, respectively at 20, 40 and 60 DAS. At 20 DAS $W_3$ was statistically on par with $W_2$ and $W_1$. However, at 40 DAS it was on par with all weed management practices except $W_7$ and at 60 DAS it was on par with $W_1$.

Interaction between seed bed preparation and weed management practices was significant only at 20 and 60 DAS. The treatment combination, $s_1w_2$ recorded the highest root fresh weight which was on par with $s_1w_1$, $s_1w_3$ and $s_1w_6$ at 20 DAS. However, at 60 DAS, $s_1w_3$ recorded the highest fresh root weight and was statistically on par with $s_1w_1$. At all the three stages of observation, $s_2w_8$ recorded the lowest root fresh weight.

### 4.4.2 Root Volume (Table 13 and 13a)

Root volume was significantly influenced by seed bed preparation only at 20 DAS and SSB recorded the highest root volume (6.71 $cm^3$). At 40 and 60 DAS no significant difference was observed.

Critical evaluation of data on root volume revealed that weed management practices had significant effect on root volume at 20, 40 and 60 DAS. At 20 DAS, treatments $W_1$, $W_3$ and $W_6$ recorded the highest root volume (6.93 $cm^3$) which was on par with $W_2$ and $W_4$. At 40 DAS, $W_2$ recorded the highest root volume of 24.36 $cm^3$ and it was on par with $W_5$, $W_6$ and $W_3$. However, at 60 DAS the treatments $W_1$, $W_3$ and $W_7$ recorded the highest root volume (26.28 $cm^3$) and were on par with $W_5$ and $W_2$. Weedy check ($W_8$) recorded the lowest root volume at all the three stages.

Interaction effect was significant only at 20 and 60 DAS. At 20 DAS the treatment combination $s_1w_1$, $s_1w_3$ and $s_1w_6$ recorded the highest root volume which was significantly superior to other treatments. However, at 60 DAS, $s_1w_1$ recorded the highest root volume which was statistically at par with $s_1w_3$ and $s_2w_7$.

## 4.5 YIELD PARAMETERS AND YIELD

### 4.5.1 Days to 50 Per Cent Flowering (Table 14 and 14a)

Days to 50 per cent flowering was significantly influenced by the seed bed preparation. Stale seed bed method took lesser number of days (43 days) to reach 50 per cent of flowering compared to normal seed bed (43.6 days).

Weed management practices and interaction between seed bed preparation and weed management practices did not have any significant effect on days to 50 per cent flowering.

### 4.5.2 Number of Pods Per Plant (Table 14 and 14a)

Number of pods per plant was significantly influenced by seed bed preparation and SSB recorded the highest number of pods per plant (36.9) as compared to normal seed bed (32.6).

Among the weed management practices $W_3$ recorded the highest number of pods per plant (44.0) which was statistically comparable with $W_2$ (42.3) and number of pods per plant the lowest in $W_8$.

Interaction effect had significant influence on the number of pods per plant. The treatment combination $s_1w_3$ recorded the highest number of pods per plant (44.7) which was statistically on par with $s_1w_2$, $s_2w_3$ and $s_2w_2$.

### 4.5.3 Pod Length (Table 14 and 14a)

Seed bed preparation had significant effect on pod length. Pod length of 15.10 cm was recorded under SSB as against the pod length of 14.87 cm in normal seed bed.

Data revealed that pod length was the highest in $W_7$ treatment which was statistically comparable with other weed treatments except $W_4$, $W_6$ and $W_8$.

Interaction effects were found to be non-significant.

Table 12. Effect of seed bed preparation and weed management practices on root fresh weight per plant

| Treatments | Root fresh weight (g per plant) | | |
|---|---|---|---|
| | 20 DAS | 40 DAS | 60 DAS |
| Seed bed preparation (S) | | | |
| $s_1$ | 6.73 | 10.01 | 19.49 |
| $s_2$ | 5.44 | 9.99 | 17.18 |
| SE m (±) | 0.07 | 0.22 | 0.29 |
| CD (0.05) | 0.20 | NS | 0.83 |
| Weed management practices (W) | | | |
| $w_1$ | 6.82 | 10.15 | 20.43 |
| $w_2$ | 6.95 | 10.62 | 19.11 |
| $w_3$ | 7.09 | 10.96 | 21.89 |
| $w_4$ | 5.41 | 10.32 | 16.27 |
| $w_5$ | 5.66 | 10.14 | 17.34 |
| $w_6$ | 6.40 | 10.19 | 17.26 |
| $w_7$ | 5.26 | 9.34 | 18.87 |
| $w_8$ | 5.12 | 8.28 | 15.50 |
| SE m (±) | 0.14 | 0.44 | 0.81 |
| CD (0.05) | 0.39 | 1.27 | 2.35 |

NS: non-significant

Table 12a. Interaction effect of seed bed preparation and weed management practices on root fresh weight per plant

| Treatments | Root fresh weight ( g per plant) | | |
|---|---|---|---|
| | 20 DAS | 40 DAS | 60 DAS |
| $s_1w_1$ | 7.56 | 11.08 | 23.24 |
| $s_1w_2$ | 7.77 | 10.23 | 20.40 |
| $s_1w_3$ | 7.56 | 11.38 | 24.39 |
| $s_1w_4$ | 5.69 | 10.04 | 16.51 |
| $s_1w_5$ | 6.31 | 9.96 | 17.83 |
| $s_1w_6$ | 7.56 | 9.26 | 17.66 |
| $s_1w_7$ | 5.67 | 9.33 | 20.72 |
| $s_1w_8$ | 5.72 | 8.78 | 15.17 |
| $s_2w_1$ | 6.08 | 9.22 | 17.63 |
| $s_2w_2$ | 6.13 | 11.02 | 17.82 |
| $s_2w_3$ | 6.61 | 10.55 | 19.38 |
| $s_2w_4$ | 5.13 | 10.59 | 16.04 |
| $s_2w_5$ | 5.01 | 10.32 | 16.86 |
| $s_2w_6$ | 5.23 | 11.02 | 16.86 |
| $s_2w_7$ | 4.84 | 9.35 | 17.02 |
| $s_2w_8$ | 4.52 | 7.78 | 15.83 |
| SE m (±) | 0.19 | 0.62 | 0.81 |
| CD (0.05) | 0.55 | NS | 2.35 |

NS: non-significant

Table 13. Effect of seed bed preparation and weed management practices on root volume

| Treatments | Root volume ($cm^3$) | | |
|---|---|---|---|
| | 20 DAS | 40 DAS | 60 DAS |
| Seed bed preparation (S) | | | |
| $S_1$ | 6.71 | 22.44 | 25.16 |
| $S_2$ | 6.03 | 22.28 | 24.84 |
| SE m (±) | 0.13 | 0.24 | 0.28 |
| CD (0.05) | 0.38 | NS | NS |
| Weed management practices (W) | | | |
| $W_1$ | 6.93 | 22.43 | 26.28 |
| $W_2$ | 6.63 | 24.36 | 25.00 |
| $W_3$ | 6.93 | 23.08 | 26.28 |
| $W_4$ | 6.33 | 21.16 | 23.72 |
| $W_5$ | 6.03 | 23.72 | 25.64 |
| $W_6$ | 6.93 | 23.72 | 24.36 |
| $W_7$ | 5.73 | 21.80 | 26.28 |
| $W_8$ | 5.43 | 18.59 | 22.44 |
| SE m (±) | 0.26 | 0.49 | 0.55 |
| CD (0.05) | 0.76 | 1.41 | 1.60 |

NS: non-significant

Table 13a. Interaction effect of seed bed preparation and weed management practices on root volume

| Treatments | Root volume ($cm^3$) | | |
|---|---|---|---|
| | 20 DAS | 40 DAS | 60 DAS |
| $s_1w_1$ | 7.84 | 24.36 | 28.21 |
| $s_1w_2$ | 6.63 | 24.36 | 25.64 |
| $s_1w_3$ | 7.84 | 24.36 | 26.93 |
| $s_1w_4$ | 6.03 | 20.51 | 23.08 |
| $s_1w_5$ | 6.03 | 23.08 | 25.64 |
| $s_1w_6$ | 7.84 | 23.06 | 24.36 |
| $s_1w_7$ | 6.03 | 21.80 | 25.64 |
| $s_1w_8$ | 5.43 | 17.95 | 21.80 |
| $s_2w_1$ | 6.03 | 23.08 | 24.36 |
| $s_2w_2$ | 6.63 | 24.36 | 24.36 |
| $s_2w_3$ | 6.03 | 21.80 | 25.64 |
| $s_2w_4$ | 6.63 | 21.80 | 24.36 |
| $s_2w_5$ | 6.03 | 24.36 | 25.64 |
| $s_2w_6$ | 6.03 | 21.80 | 24.36 |
| $s_2w_7$ | 5.43 | 21.80 | 26.93 |
| $s_2w_8$ | 5.13 | 19.23 | 23.08 |
| SE m (±) | 0.37 | 0.69 | 0.78 |
| CD (0.05) | 1.07 | NS | 2.26 |

NS: non-significant

**4.5.4 Pod Girth (Table 14 and 14a)**

Seed bed preparation had no significant effect on pod girth.

Among the weed management practices, $W_3$ recorded the highest pod girth and it was significantly superior to other treatments and pod girth was the lowest in weedy check treatment ($W_8$).

Interaction effect had no significant influence on pod girth.

**4.5.5 Pod Weight (Table 14 and 14a)**

Pod weight was significantly influenced by seed bed preparation and SSB recorded the highest pod weight of 2.44 g compared to normal seed bed (2.35 g).

The results on pod weight revealed that the highest pod weight recorded in $W_3$ which was statistically comparable with other weed management practices except $W_6$, $W_4$ and $W_8$.

Interaction effect was significant and the treatment combination $s_1w_3$ recorded the highest pod weight of 2.68 g which was statistically on par with $s_1w_2$, $s_1w_1$, $s_1w_6$ and $s_1w_4$.

**4.5.6 Green Pod Yield Per Plant (Table 15 and 15a)**

Green pod yield per plant was significantly influenced by seed bed preparation. Stale seed bed recorded the highest green pod yield per plant (90.50 g) which was significantly superior to normal seed bed (76.69 g).

Between the weed management practices, the highest green pod yield per plant was registered in $W_3$ (110.73 g) which was significantly superior to other weed management practices. The treatment $W_3$ was followed by $W_2$ and $W_1$ and these two treatments were significantly superior to other weed management treatments. The lowest green pod yield per plant (45.21 g) was recorded in $W_8$ which was significantly inferior to other treatments.

Interaction effect was significant and the highest green pod yield per plant was recorded in $s_1w_3$ (119.66 g) which was significantly superior over other treatments and it was followed by $s_1w_2$ and $s_1w_1$. The lowest green pod yield per plant (35.44 g) was recorded in the treatment combination $s_2w_8$ which was significantly inferior to all other treatment combinations.

**4.5.7 Total Green Pod Yield Per Hectare (Table 15 and 15a)**

Data on seed bed preparation revealed that SSB recorded significantly higher green pod yield of 6286.2 kg $ha^{-1}$ as compared with normal seed bed (5638.1 kg $ha^{-1}$).

Weed management practices had significant effect on green pod yield $ha^{-1}$ and followed the same trend as that of green pod yield per plant. The treatment $W_3$ recorded the highest green pod yield $ha^{-1}$ (7589.0 kg $ha^{-1}$) and it was on par with $W_2$ and $W_2$ was on par with $W_1$. Weedy check ($W_8$) recorded significantly lower pod yield per $ha^{-1}$ (3113.7 kg $ha^{-1}$).

The interaction effect had significant impact on green pod yield $ha^{-1}$ and the treatment combination $s_1w_3$ recorded the highest yield which was statistically comparable with $s_1w_2$, $s_2w_3$ and $s_1w_1$. The treatment combination $s_2w_8$ recorded the lowest green pod yield and it was significantly inferior among other treatments.

**4.5.8 Dry Haulm Yield Per Plant (Table 15 and 15a)**

Seed bed preparation had no significant effect on dry haulm yield per plant.

Data on dry haulm yield per plant revealed that it was favourably influenced by weed management practices. The treatment $W_6$ recorded the highest dry haulm yield per plant and was significantly on par with $W_5$ and $W_1$. The dry haulm yield per plant was the lowest in $W_4$ which was at par with $W_3$, $W_7$, $W_2$ and $W_8$.

Interaction effect had significant influence on dry haulm yield per plant. The treatment combination $s_1w_6$ recorded the highest dry haulm yield per plant and the lowest haulm yield per plant was recorded by the treatment combination $s_1w_4$.

**4.5.9 Dry Haulm Yield Per Hectare (Table 15 and 15a)**

Manipulation of seed bed had no significant effect on dry haulm yield $ha^{-1}$.

Weed management practices had significant effect on dry haulm yield $ha^{-1}$. It followed the same trend as that of dry haulm yield per plant and the highest haulm yield $ha^{-1}$ as recorded by $W_6$ (5512.8 kg $ha^{-1}$) and the lowest by $W_4$ (4743.6 kg $ha^{-1}$).

Interaction effect also had significant impact on dry haulm yield $ha^{-1}$. The treatment combination $s_1w_6$ recorded the highest haulm yield $ha^{-1}$ and the lowest by $s_1w_4$.

**4.5.10 Harvest index (HI) (Table 16 and 16a)**

Seed bed preparation had significant effect on harvest index. Stale seed bed recorded the highest HI of 0.234 as against the HI of 0.215 in normal seed bed.

Harvest index was also significantly influenced by weed management practices. The treatment $W_3$ recorded the highest HI (0.278) which was on par with $W_2$ and the HI was the lowest in weedy check ($W_8$) (0.135).

Interaction effect had significant influence on HI of bush type vegetable cowpea. The treatment combination, $s_1w_3$ recorded the highest HI (0.279) which was on par with $s_2w_3$, $s_1w_2$, $s_2w_2$ and $s_1w_1$.

**4.5.11 Weed index (WI) (Table 16 and 16a)**

Weed index was significantly influenced by seed bed preparation. Stale seed bed registered the lowest WI of 18.61 as against the WI of 26.65 in normal seed bed.

Among the weed management practices, $W_3$ recorded the lowest WI (1.81) which was significantly different from all other treatments. The treatment $W_3$ was followed by $W_2$ which was also significantly superior compared to other treatments. The highest weed index was recorded in $W_8$ (59.70).

Interaction effect was significant and WI was the lowest in $s_1w_3$ (0.00). The treatment combination $s_1w_3$ was followed by $s_1w_2$ which was statistically on par with $s_2w_3$. The highest WI was recorded in the treatment combination $s_2w_8$ (69.87) which was significantly inferior to all other treatment combinations.

4.6 QUALITY PARAMETERS

**4.6.1 Protein Content of the Pod (Table 16 and 16a)**

Protein content of the pod was significantly influenced by seed bed preparation. Stale seed bed recorded the highest per cent of protein (19.69 per cent) and was superior to normal seed bed (16.07 per cent).

Weed management practices also significantly influenced the protein content of the pod. Data on protein content of the pod indicated that the highest protein content was registered in the treatment $W_1$ (21.88 per cent) which was on par with $W_3$. Weedy check recorded the lowest protein content among the treatments (13.13 per cent).

Interaction effect had no significant impact on protein content of pod.

4.7 OBSERVATION ON WEEDS

**4.7.1 Weed Flora (Table 17)**

Grassy weeds, sedges and BLW were present in the experimental field. Among the grassy weeds, *Setaria barbata* and *Digitaria sanguinalis* were the major ones, *Spermacoce latifolia*, *Alternanthera sessilis*, *Phyllanthus niruri* and *Synedrella nodiflora* were the dominant BLW present in the experimental field. The population of sedges was very low and *Cyperus rotundus* was the only sedge present in the experimental field.

**4.7.2 Absolute Density of Grasses (Table 18, 18a, 19, 19a, 20 and 20a)**

Absolute density of grasses was significantly influenced by seed bed preparation. At 15, 30 and 45 DAS, SSB recorded significantly lower absolute density of grasses of 25.75, 29.67 and 12.21 no. $m^{-2}$, respectively compared to normal seed bed which recorded the absolute density of grasses of 39.83, 38.67 and 21.75 no. $m^{-2}$ respectively.

Weed management practices also significantly influenced the absolute density of grasses at 15, 30 and 45 DAS. At 15 DAS, $W_3$ recorded the lowest absolute density of grassy weeds was statistically on par with other weed management treatments except, $W_8$ $W_7$ and $W_4$. At 30 DAS also $W_3$ recorded the absolute lowest density of grassy weeds but it was statistically on par with $W_1$ and $W_2$. However, at 45 DAS $W_1$ and $W_3$ recorded the lowest absolute density of grasses which was significantly superior to other treatments. Weedy check recorded the highest absolute density of grassy weeds at all the three stages of observation.

Interaction effect was also significant and the treatment combination $s_1w_5$ at 15 DAS, $s_1w_2$ and $s_1w_1$ at 30 DAS and $s_1w_1$ and $s_1w_3$ at 45 DAS recorded the lowest absolute density of grassy weeds.

Table 14. Effect of seed bed preparation and weed management practices on yield attributes

| Treatments | Days to 50 per cent flowering | No. of green pods per plant | Green pod girth (cm) | Green pod length (cm) | Green pod weight per plant (g) |
|---|---|---|---|---|---|
| Seed bed preparation (S) | | | | | |
| $S_1$ | 43.0 | 36.9 | 2.12 | 15.10 | 2.44 |
| $S_2$ | 43.6 | 32.6 | 2.12 | 14.87 | 2.35 |
| SE m (±) | 0.19 | 0.42 | 0.01 | 0.05 | 0.03 |
| CD (0.05) | 0.55 | 1.2 | NS | 0.14 | 0.07 |
| Weed management practices | | | | | |
| $W_1$ | 43.2 | 39.2 | 2.12 | 15.14 | 2.50 |
| $W_2$ | 42.6 | 42.3 | 2.14 | 15.21 | 2.47 |
| $W_3$ | 43.3 | 44.0 | 2.20 | 15.23 | 2.56 |
| $W_4$ | 44.0 | 30.0 | 2.13 | 14.55 | 2.41 |
| $W_5$ | 42.8 | 33.5 | 2.10 | 15.07 | 2.32 |
| $W_6$ | 43.2 | 32.0 | 2.13 | 14.94 | 2.39 |
| $W_7$ | 43.0 | 36.7 | 2.12 | 15.32 | 2.35 |
| $W_8$ | 44.3 | 21.2 | 2.00 | 14.45 | 2.17 |
| SE m (±) | 0.38 | 0.84 | 0.02 | 0.09 | 0.05 |
| CD (0.05) | NS | 2.6 | 0.05 | 0.27 | 0.15 |

NS: non-significant

Table 14a. Interaction effect of seed bed preparation and weed management practices on yield attributes

| Treatments | Days to 50 per cent flowering | No. of green pods per plant | Green pod girth, cm | Green pod length, cm | Green pod weight per plant (g) |
|---|---|---|---|---|---|
| $s_1w_1$ | 43.0 | 40.7 | 2.13 | 15.25 | 2.56 |
| $s_1w_2$ | 43.0 | 43.0 | 2.11 | 15.34 | 2.63 |
| $s_1w_3$ | 43.0 | 44.7 | 2.20 | 15.30 | 2.68 |
| $s_1w_4$ | 44.0 | 31.3 | 2.10 | 14.55 | 2.49 |
| $s_1w_5$ | 42.7 | 37.7 | 2.10 | 15.28 | 2.31 |
| $s_1w_6$ | 42.7 | 32.0 | 2.17 | 15.63 | 2.50 |
| $s_1w_7$ | 42.3 | 39.3 | 2.13 | 15.36 | 2.28 |
| $s_1w_8$ | 43.3 | 26.7 | 2.00 | 14.70 | 2.07 |
| $s_2w_1$ | 43.3 | 37.7 | 2.10 | 15.02 | 2.44 |
| $s_2w_2$ | 42.3 | 41.7 | 2.17 | 15.09 | 2.31 |
| $s_2w_3$ | 43.7 | 42.0 | 2.20 | 15.16 | 2.43 |
| $s_2w_4$ | 44.0 | 28.7 | 2.17 | 14.55 | 2.32 |
| $s_2w_5$ | 43.0 | 29.3 | 2.10 | 14.86 | 2.32 |
| $s_2w_6$ | 43.7 | 32.0 | 2.10 | 14.81 | 2.27 |
| $s_2w_7$ | 43.7 | 34.0 | 2.10 | 15.27 | 2.42 |
| $s_2w_8$ | 45.3 | 15.7 | 2.00 | 14.20 | 2.27 |
| SE m (±) | 0.54 | 1.2 | 0.02 | 0.13 | 0.07 |
| CD (0.05) | NS | 3.5 | NS | NS | 0.21 |

NS: non-significant

Table 15. Effect of seed bed preparation and weed management practices on yield

| Treatments | Dry haulm yield per plant (g) | Dry haulm yield (kg ha$^{-1}$) | Green pod yield per plant (g) | Green pod yield (kg ha$^{-1}$) |
|---|---|---|---|---|
| Seed bed preparation (S) | | | | |
| $S_1$ | 30.64 | 5106.7 | 90.50 | 6286.2 |
| $S_2$ | 30.70 | 5116.8 | 76.69 | 5638.1 |
| SE m (±) | 0.38 | 63.9 | 0.72 | 60.90 |
| CD (0.05) | NS | NS | 2.08 | 176.73 |
| Weed management practices (W) | | | | |
| $W_1$ | 30.94 | 5155.8 | 97.74 | 7009.3 |
| $W_2$ | 30.57 | 5095.0 | 104.42 | 7337.3 |
| $W_3$ | 29.62 | 4936.4 | 110.73 | 7589.0 |
| $W_4$ | 28.46 | 4743.6 | 72.06 | 5103.2 |
| $W_5$ | 32.41 | 5400.8 | 77.43 | 5883.3 |
| $W_6$ | 33.08 | 5512.8 | 75.63 | 5631.8 |
| $W_7$ | 29.87 | 4977.8 | 85.52 | 6024.3 |
| $W_8$ | 30.43 | 5071.9 | 45.21 | 3113.7 |
| SE m (±) | 0.78 | 127.8 | 1.43 | 121.79 |
| CD (0.05) | 2.23 | 370.9 | 4.15 | 353.47 |

NS: non-significant

Table 15a. Interaction effect of seed bed preparation and weed management practices on yield

| Treatments | Dry haulm yield per plant (g) | Dry haulm yield (kg ha$^{-1}$) | Green pod yield per plant (g) | Green pod yield (kg ha$^{-1}$) |
|---|---|---|---|---|
| $s_1w_1$ | 31.56 | 5260.0 | 103.94 | 7226.3 |
| $s_1w_2$ | 30.89 | 5145.3 | 112.75 | 7483.3 |
| $s_1w_3$ | 30.08 | 5013.9 | 119.66 | 7731.7 |
| $s_1w_4$ | 27.10 | 4516.7 | 77.59 | 5490.7 |
| $s_1w_5$ | 32.45 | 5408.3 | 86.87 | 6047.0 |
| $s_1w_6$ | 34.02 | 5670.6 | 79.02 | 5986.0 |
| $s_1w_7$ | 31.57 | 5262.2 | 89.15 | 6429.0 |
| $s_1w_8$ | 27.44 | 4573.9 | 54.98 | 3895.3 |
| $s_2w_1$ | 30.31 | 5501.7 | 91.54 | 6792.3 |
| $s_2w_2$ | 30.25 | 5041.7 | 96.09 | 7191.3 |
| $s_2w_3$ | 29.15 | 4858.9 | 101.79 | 7446.3 |
| $s_2w_4$ | 29.82 | 4970.6 | 66.59 | 4715.7 |
| $s_2w_5$ | 32.36 | 5393.3 | 67.99 | 5729.7 |
| $s_2w_6$ | 32.13 | 5355.0 | 72.23 | 5277.7 |
| $s_2w_7$ | 28.16 | 4693.3 | 81.90 | 5619.7 |
| $s_2w_8$ | 33.42 | 5570.0 | 35.44 | 2332.0 |
| SE m (±) | 1.09 | 180.8 | 2.02 | 172.24 |
| CD (0.05) | 3.15 | 524.6 | 5.87 | 499.9 |

Table 16. Effect of seed bed preparation and weed management practices on protein content of pod, weed index and harvest index

| Treatments | Protein content (%) | Weed index (%) | | Harvest index |
|---|---|---|---|---|
| Seed bed preparation (S) | | | | |
| $s_1$ | 19.69 | 4.42 | (18.61) | 0.234 |
| $s_2$ | 16.07 | 5.26 | (26.65) | 0.215 |
| SE m (±) | 0.54 | 0.05 | | 0.003 |
| CD (0.05) | 1.55 | 0.13 | | 0.009 |
| Weed management practices (W) | | | | |
| $w_1$ | 21.88 | 3.18 | (9.14) | 0.254 |
| $w_2$ | 19.69 | 2.46 | (5.06) | 0.265 |
| $w_3$ | 21.15 | 1.68 | (1.81) | 0.278 |
| $w_4$ | 13.85 | 5.91 | (33.92) | 0.213 |
| $w_5$ | 16.88 | 4.98 | (23.81) | 0.214 |
| $w_6$ | 18.23 | 5.16 | (25.62) | 0.204 |
| $w_7$ | 18.23 | 5.29 | (21.97) | 0.232 |
| $w_8$ | 13.13 | 7.78 | (59.70) | 0.135 |
| SE m (±) | 1.07 | 0.09 | | 0.006 |
| CD (0.05) | 3.11 | 0.27 | | 0.018 |

Values in parentheses are original values; values are subjected to square root transformation $\sqrt{(x+1)}$

Table 16a. Interaction effect of seed bed preparation and weed management practices on protein content of pod, weed index and harvest index

| Treatments | Protein content (%) | Weed index (%) | | Harvest index |
|---|---|---|---|---|
| $s_1w_1$ | 24.79 | 2.70 | (6.31) | 0.256 |
| $s_1w_2$ | 21.88 | 2.06 | (3.24) | 0.268 |
| $s_1w_3$ | 23.33 | 1.00 | (0.00) | 0.279 |
| $s_1w_4$ | 14.58 | 5.47 | (28.96) | 0.233 |
| $s_1w_5$ | 18.96 | 4.77 | (21.75) | 0.219 |
| $s_1w_6$ | 20.42 | 4.83 | (22.30) | 0.210 |
| $s_1w_7$ | 20.42 | 4.21 | (16.74) | 0.234 |
| $s_1w_8$ | 13.13 | 7.11 | (19.52) | 0.176 |
| $s_2w_1$ | 18.96 | 3.60 | (11.93) | 0.252 |
| $s_2w_2$ | 17.50 | 2.81 | (6.88) | 0.263 |
| $s_2w_3$ | 18.96 | 2.14 | (3.60) | 0.277 |
| $s_2w_4$ | 13.13 | 6.32 | (38.89) | 0.192 |
| $s_2w_5$ | 14.79 | 5.18 | (25.87) | 0.210 |
| $s_2w_6$ | 16.04 | 5.47 | (28.96) | 0.198 |
| $s_2w_7$ | 16.04 | 5.31 | (27.20) | 0.230 |
| $s_2w_8$ | 13.13 | 8.42 | (69.87) | 0.095 |
| SE m (±) | 1.52 | 0.13 | | 0.009 |
| CD (0.05) | NS | 0.38 | | 0.025 |

Values in parentheses are original values; values are subjected to square root transformation $\sqrt{(x+1)}$, NS: non-significant

### 4.7.3 Absolute Density of Sedges (Table 18, 18a, 19, 19a, 20 and 20a)

Seed bed preparation did not have any significant influence on the absolute density of sedges at 15, 30 and 45 DAS.

Absolute density of sedges was favourably influenced by weed management practices only at 45 DAS. Sedges were found only in the treatments $W_3$, $W_4$, $W_5$ and $W_7$. Among these treatments, the lowest absolute density of sedges was observed in $W_3$ and $W_7$.

Interaction effect was significant only at 45 DAS. Sedges were present only in the treatment combinations $s_1w_3$, $s_1w_5$, $s_2w_4$, $s_2w_5$, $s_2w_7$ and $s_2w_8$ and among these treatments, $s_1w_5$ recorded the highest absolute density of sedges which was on par with $s_2w_4$.

### 4.7.4 Absolute Density of BLW (Table 18, 18a, 19, 19a, 20 and 20a)

Absolute density of BLW was significantly influenced by seed bed preparation. Stale seed bed recorded significantly lower BLW population of 18.33, 22.00 and 21.17 no $m^{-2}$, respectively as against the absolute density of BLW of 28.50, 42.83 and 23.00, no. $m^{-2}$ in normal seed bed.

Perusal of data on absolute density of BLW revealed that it was significantly influenced by weed management practices at 15, 30 and 45 DAS. At 15 DAS, $W_5$ recorded significantly lower absolute density of BLW which was statistically comparable with all weed management treatments except $W_7$. However, at 30 DAS $W_3$ recorded the lowest absolute density of BLW which was on par with $W_5$ and at 45 DAS, $W_2$ recorded significantly lower absolute density of BLW compared to other weed management treatments. At all the three stages of observation, weedy check recorded significantly higher absolute density of BLW.

Interaction effect was significant only at 30 and 45 DAS. At 30 and 45 DAS, $s_1w_2$ recorded the lowest absolute density of BLW. However, at 30 DAS it was statistically on par with $s_1w_3$ and $s_1w_5$.

### 4.7.5 Total Weed Density (Table 21 and 21a)

Total weed density was significantly influenced by seed bed preparation at 15, 30 and 45 DAS. Stale seed bed recorded the lowest weed density at 15, 30 and 45 DAS (45.58, 51.67 and 34.05 no $m^{-2}$, respectively) compared to normal seed bed (70.83, 81.50 and 45.42 no $m^{-2}$, respectively).

From 15 to 30 DAS, an increase in total density of weeds was observed and from 30 to 45 DAS a decline in the total density of weeds was observed in all the weed management treatments. Among the weed management practices $W_5$ recorded the lowest total weed density at 15 DAS which was statistically on par with $W_2$, $W_6$, $W_1$, $W_3$ and $W_4$. At 30 DAS, $W_3$ recorded the lowest weed density which was significantly superior to other treatments, however at 45 DAS, $W_1$ recorded the lowest weed density which was statistically comparable with $W_2$ and $W_3$. At all the three stages weedy check recorded the highest total weed density (164.67, 143.33 and 104.67 no. $m^{-2}$, respectively).

Interaction effect was significant at all the three stages. At 15 DAS, $s_1w_5$ recorded the lowest weed density which was statistically on par with all treatments except $s_2w_1$, $s_2w_6$, $s_1w_4$, $s_2w_3$, $s_1w_7$, $s_2w_7$, $s_1w_8$ and $s_2w_8$. At 30 and 45 DAS, $s_1w_2$ recorded the lowest total weed density. However, at 30 DAS it was statistically on par with $s_1w_3$ at 30 DAS and at 45 DAS it was statistically on par with $s_1w_1$.

### 4.7.6 Relative Density of Grasses (Table 22, 22a, 23, 23a, 24 and 24a)

Seed bed preparation had no significant impact on relative density of grasses at 15 DAS. However, at 30 and 45 DAS, it had significant effect. Normal seed bed recorded the lowest relative density of grasses at 30 and 45 DAS compared to SSB.

Similar to seed bed preparation, weed management practices also had significant effect on relative density of grasses at 15, 30 and 45 DAS. The treatment $W_3$ recorded the lowest relative density of grasses (45.21 per cent) at 15 DAS and weedy check ($W_8$) recorded the highest. At 30 DAS, the lowest relative density of grasses was observed in $W_8$ and the highest in $W_5$ and at 45 DAS the lowest relative density of grasses was observed in $w_6$ and the highest in $W_1$.

Table 17. Predominant weed flora of the experimental plot

| Scientific name | Common name | Malayalam name |
| --- | --- | --- |
| Broad leaved weeds | | |
| *Spermacoce latifolia* | False button weed | Vellatharavu/Pachhappala |
| *Alternanthera sessilis* | Aligator weed | Ponnankannikkira |
| *Phyllanthus niruri* | Stone breaker weed | Keezharnelli |
| *Synedrella nodiflora* | Cindrella weed | Mudiyethra Pacha |
| Grasses | | |
| *Setaria barbata* | East Indian bristle grass | |
| *Digitaria sanguinalis* | Crab grass | |
| Sedges | | |
| *Cyperus rotundus* | Purple nutsedge | Muthanga |

Table 18. Effect of seed bed preparation and weed management practices on absolute density (Ad) of weeds at 15 DAS

| Treatments | Grasses (no. m$^{-2}$) | | Sedges (no. m$^{-2}$) | | BLW (no. m$^{-2}$) | |
|---|---|---|---|---|---|---|
| Seed bed preparation (S) | | | | | | |
| $S_1$ | 5.17 | (25.75) | 1.58 | (1.50) | 4.40 | (18.33) |
| $S_2$ | 6.39 | (39.83) | 1.87 | (2.50) | 5.43 | (28.50) |
| SE m (±) | 0.14 | | 0.19 | | 0.23 | |
| CD (0.05) | 0.40 | | NS | | 0.66 | |
| Weed management practices (W) | | | | | | |
| $W_1$ | 4.61 | (20.33) | 1.00 | (0.00) | 4.43 | (18.67) |
| $W_2$ | 4.73 | (21.33) | 1.53 | (1.33) | 4.12 | (16.00) |
| $W_3$ | 4.43 | (18.67) | 2.77 | (6.67) | 4.36 | (18.00) |
| $W_4$ | 7.54 | (23.33) | 1.00 | (0.00) | 4.87 | (22.67) |
| $W_5$ | 4.93 | (23.33) | 1.92 | (2.67) | 3.65 | (11.33) |
| $W_6$ | 4.93 | (23.33) | 1.29 | (0.67) | 3.96 | (14.67) |
| $W_7$ | 5.51 | (29.33) | 2.24 | (4.00) | 5.07 | (24.67) |
| $W_8$ | 10.18 | (102.67) | 1.29 | (0.67) | 7.89 | (61.33) |
| SE m (±) | 0.28 | | 0.37 | | 0.45 | |
| CD (0.05) | 0.81 | | NS | | 1.31 | |

Values in parentheses are original values, data are subjected to square root transformation $\sqrt{(x+1)}$, NS: non-significant

Table 18a. Interaction effect of seed bed preparation and weed management practices on absolute density (Ad) of weeds at 15 DAS

| Treatments | Grasses (no. $m^{-2}$) | | Sedges (no. $m^{-2}$) | | BLW (no. $m^{-2}$) | |
|---|---|---|---|---|---|---|
| $s_1w_1$ | 4.51 | (19.33) | 0.00 | (0.00) | 3.41 | (10.67) |
| $s_1w_2$ | 4.28 | (17.33) | 1.92 | (2.67) | 3.61 | (12.00) |
| $s_1w_3$ | 3.96 | (14.67) | 2.52 | (5.33) | 3.96 | (14.67) |
| $s_1w_4$ | 5.00 | (24.00) | 1.00 | (0.00) | 5.13 | (25.33) |
| $s_1w_5$ | 3.79 | (13.33) | 1.92 | (2.67) | 3.41 | (10.67) |
| $s_1w_6$ | 4.12 | (16.00) | 1.53 | (1.33) | 3.61 | (12.00) |
| $s_1w_7$ | 5.74 | (32.00) | 1.00 | (0.00) | 4.73 | (21.33) |
| $s_1w_8$ | 8.39 | (69.33) | 1.00 | (0.00) | 6.40 | (40.00) |
| $s_2w_1$ | 4.73 | (21.33) | 1.00 | (0.00) | 5.26 | (26.67) |
| $s_2w_2$ | 5.13 | (25.33) | 1.00 | (0.00) | 4.58 | (20.00) |
| $s_2w_3$ | 4.87 | (22.67) | 3.00 | (8.00) | 4.73 | (21.33) |
| $s_2w_4$ | 4.87 | (22.67) | 1.00 | (0.00) | 4.58 | (20.00) |
| $s_2w_5$ | 5.86 | (33.33) | 1.92 | (2.67) | 3.61 | (12.00) |
| $s_2w_6$ | 5.63 | (30.67) | 1.00 | (0.00) | 4.28 | (17.33) |
| $s_2w_7$ | 5.26 | (29.67) | 3.00 | (8.00) | 5.39 | (28.00) |
| $s_2w_8$ | 117.0 | (136.00) | 1.53 | (1.33) | 9.15 | (82.67) |
| SE m (±) | 0.39 | | 0.52 | | 0.64 | |
| CD (0.05) | 1.14 | | NS | | NS | |

Values in parentheses are original values, data are subjected to square root transformation $\sqrt{(x+1)}$, NS: Non-significant.

Table 19. Effect of seed bed preparation and weed management practices on absolute density (Ad) of weeds at 30 DAS

| Treatments | Grasses (no. $m^{-2}$) | | Sedges (no. $m^{-2}$) | BLW (no. $m^{-2}$) | |
|---|---|---|---|---|---|
| Seed bed preparation (S) | | | | | |
| $S_1$ | 5.54 | (29.67) | 0.00 | 4.80 | (22.00) |
| $S_2$ | 6.30 | (38.67) | 0.00 | 6.62 | (42.83) |
| SE m (±) | 0.11 | | - | 0.09 | |
| CD (0.05) | 0.32 | | - | 0.25 | |
| Weed management practices (W) | | | | | |
| $W_1$ | 4.58 | (20.00) | 0.00 | 4.87 | (22.67) |
| $W_2$ | 4.73 | (21.33) | 0.00 | 5.00 | (24.00) |
| $W_3$ | 4.51 | (19.33) | 0.00 | 3.21 | (9.33) |
| $W_4$ | 7.54 | (56.00) | 0.00 | 6.51 | (41.33) |
| $W_5$ | 5.45 | (28.67) | 0.00 | 3.32 | (10.00) |
| $W_6$ | 5.63 | (30.67) | 0.00 | 5.13 | (25.33) |
| $W_7$ | 7.05 | (48.67) | 0.00 | 5.74 | (32.00) |
| $W_8$ | 7.05 | (48.67) | 0.00 | 9.78 | (94.67) |
| SE m (±) | 0.22 | | - | 0.17 | |
| CD (0.05) | 0.63 | | - | 0.50 | |

Values in parentheses are original values, data are subjected to square root transformation $\sqrt{(x+1)}$

Table 19a. Interaction effect of seed bed preparation and weed management practices on absolute density (Ad) of weeds at 30 DAS

| Treatments | Grasses (no. m$^{-2}$) | | Sedges (no. m$^{-2}$) | BLW (no. m$^{-2}$) | |
|---|---|---|---|---|---|
| $s_1w_1$ | 4.28 | (17.33) | 0.00 | 4.44 | (18.70) |
| $s_1w_2$ | 4.28 | (17.33) | 0.00 | 2.52 | (5.33) |
| $s_1w_3$ | 4.58 | (20.00) | 0.00 | 3.00 | (8.00) |
| $s_1w_4$ | 6.81 | (45.33) | 0.00 | 5.00 | (24.00) |
| $s_1w_5$ | 5.39 | (28.00) | 0.00 | 3.00 | (8.00) |
| $s_1w_6$ | 5.26 | (26.67) | 0.00 | 3.79 | (13.33) |
| $s_1w_7$ | 6.08 | (36.00) | 0.00 | 5.86 | (33.33) |
| $s_1w_8$ | 6.90 | (46.67) | 0.00 | 8.14 | (65.33) |
| $s_2w_1$ | 4.87 | (22.67) | 0.00 | 5.26 | (26.67) |
| $s_2w_2$ | 5.13 | (25.33) | 0.00 | 6.61 | (42.67) |
| $s_2w_3$ | 4.44 | (18.67) | 0.00 | 3.42 | (10.67) |
| $s_2w_4$ | 8.23 | (66.67) | 0.00 | 7.72 | (58.67) |
| $s_2w_5$ | 5.51 | (29.33) | 0.00 | 3.61 | (12.00) |
| $s_2w_6$ | 5.97 | (34.67) | 0.00 | 6.19 | (37.33) |
| $s_2w_7$ | 7.89 | (61.33) | 0.00 | 5.63 | (30.67) |
| $s_2w_8$ | 7.19 | (50.67) | 0.00 | 11.18 | (124.00) |
| SE m (±) | 0.31 | | - | 0.24 | |
| CD (0.05) | 0.90 | | - | 0.71 | |

Values in parentheses are original values, data are subjected to square root transformation $\sqrt{(x+1)}$.

Table 20. Effect of seed bed preparation and weed management practice on absolute density (Ad) of weeds at 45 DAS

| Treatments | Grasses (no. m$^{-2}$) | | Sedges (no. m$^{-2}$) | | BLW (no. m$^{-2}$) | |
|---|---|---|---|---|---|---|
| Seed bed preparation (S) | | | | | | |
| $S_1$ | 3.63 | (12.21) | 1.29 | (0.67) | 4.70 | (21.17) |
| $S_2$ | 4.77 | (21.75) | 1.29 | (0.67) | 4.89 | (23.00) |
| SE m (±) | 0.07 | | 0.06 | | 0.05 | |
| CD (0.05) | 0.19 | | NS | | 0.15 | |
| Weed management practices (W) | | | | | | |
| $W_1$ | 2.38 | (4.67) | 1.00 | (0.00) | 3.51 | (11.33) |
| $W_2$ | 3.21 | (9.33) | 1.00 | (0.00) | 2.99 | (7.99) |
| $W_3$ | 2.38 | (4.67) | 1.29 | (0.67) | 3.87 | (14.00) |
| $W_4$ | 4.80 | (22.00) | 1.53 | (1.33) | 5.86 | (33.33) |
| $W_5$ | 3.63 | (12.17) | 1.91 | (2.67) | 4.04 | (15.33) |
| $W_6$ | 4.90 | (23.00) | 1.00 | (0.00) | 4.12 | (16.00) |
| $W_7$ | 3.42 | (10.67) | 1.29 | (0.67) | 4.93 | (23.33) |
| $W_8$ | 7.09 | (49.33) | 1.00 | (0.00) | 7.51 | (55.33) |
| SE m (±) | 0.13 | | 0.13 | | 0.10 | |
| CD (0.05) | 0.39 | | 0.37 | | 0.29 | |

Values in parentheses are original values, data are subjected to square root transformation $\sqrt{(x+1)}$, NS: non-significant

Table 20a. Interaction effect of seed bed preparation and weed management practices on absolute density (Ad) of weeds at 45 DAS

| Treatments | Grasses (no. m$^{-2}$) | | Sedges (no. m$^{-2}$) | | BLW (no. m$^{-2}$) | |
|---|---|---|---|---|---|---|
| $s_1w_1$ | 1.53 | (1.33) | 1.00 | (0.00) | 3.42 | (10.67) |
| $s_1w_2$ | 2.24 | (4.00) | 1.00 | (0.00) | 2.77 | (6.67) |
| $s_1w_3$ | 1.53 | (1.33) | 1.53 | (1.33) | 3.96 | (14.67) |
| $s_1w_4$ | 4.44 | (18.67) | 1.00 | (0.00) | 6.08 | (36.00) |
| $s_1w_5$ | 3.65 | (12.33) | 2.24 | (4.00) | 3.79 | (13.33) |
| $s_1w_6$ | 3.79 | (13.33) | 1.00 | (0.00) | 3.42 | (10.67) |
| $s_1w_7$ | 3.61 | (12.00) | 1.00 | (0.00) | 5.39 | (28.00) |
| $s_1w_8$ | 5.97 | (34.67) | 1.00 | (0.00) | 7.09 | (49.30) |
| $s_2w_1$ | 3.00 | (8.00) | 1.00 | (0.00) | 3.61 | (12.00) |
| $s_2w_2$ | 3.96 | (14.67) | 1.00 | (0.00) | 3.21 | (9.30) |
| $s_2w_3$ | 3.00 | (8.00) | 1.00 | (0.00) | 3.79 | (13.33) |
| $s_2w_4$ | 5.13 | (25.30) | 1.92 | (2.67) | 5.63 | (30.67) |
| $s_2w_5$ | 3.61 | (12.00) | 1.53 | (1.33) | 4.28 | (17.33) |
| $s_2w_6$ | 5.80 | (32.67) | 1.00 | (0.00) | 4.72 | (21.30) |
| $s_2w_7$ | 3.21 | (9.33) | 1.53 | (1.33) | 4.44 | (18.67) |
| $s_2w_8$ | 8.06 | (64.00) | 1.29 | (0.67) | 7.89 | (61.33) |
| SE m (±) | 0.19 | | 0.18 | | 0.14 | |
| CD (0.05) | 0.55 | | 0.53 | | 0.41 | |

Values in parentheses are original values, data are subjected to square root transformation $\sqrt{(x+1)}$.

Table 21. Effect of seed bed preparation and weed management practices on total weed density

| Treatment | Total weed density (no. $m^{-2}$) | | | | | |
|---|---|---|---|---|---|---|
| | 15 DAS | | 30 DAS | | 45 DAS | |
| Seed bed preparation (S) | | | | | | |
| $S_1$ | 6.82 | (45.58) | 7.26 | (51.67) | 5.92 | (34.05) |
| $S_2$ | 8.48 | (70.83) | 9.08 | (81.50) | 6.81 | (45.42) |
| SE m (±) | 0.20 | | 0.08 | | 0.10 | |
| CD (0.05) | 0.59 | | 0.23 | | 0.29 | |
| Weed management practices (W) | | | | | | |
| $W_1$ | 6.32 | (39.00) | 6.61 | (42.67) | 4.12 | (16.00) |
| $W_2$ | 6.30 | (38.67) | 6.80 | (45.33) | 4.28 | (17.33) |
| $W_3$ | 6.66 | (43.33) | 5.44 | (28.67) | 4.51 | (19.33) |
| $W_4$ | 6.86 | (46.00) | 9.91 | (97.33) | 7.58 | (56.67) |
| $W_5$ | 6.19 | (37.33) | 6.29 | (38.67) | 5.59 | (30.17) |
| $W_6$ | 6.30 | (38.67) | 7.54 | (56.00) | 6.32 | (39.00) |
| $W_7$ | 7.68 | (58.00) | 9.04 | (80.67) | 5.97 | (34.67) |
| $W_8$ | 12.67 | (164.67) | 12.01 | (143.33) | 10.2 | (104.67) |
| SE m (±) | 0.41 | | 0.16 | | 0.20 | |
| CD (0.05) | 1.18 | | 0.45 | | 0.58 | |

Values in parentheses are original values, data are subjected to square root transformation $\sqrt{(x+1)}$.

Table 21a. Interaction effect of seed bed preparation and weed management practices on total weed density

| Treatments | Total weed density (no. m$^{-2}$) | | | | | |
|---|---|---|---|---|---|---|
| | 15 DAS | | 30 DAS | | 45 DAS | |
| $s_1w_1$ | 5.56 | (30.00) | 6.08 | (36.00) | 3.61 | (12.00) |
| $s_1w_2$ | 5.74 | (32.00) | 4.85 | (22.67) | 3.42 | (10.77) |
| $s_1w_3$ | 5.97 | (34.67) | 5.39 | (28.00) | 4.28 | (17.33) |
| $s_1w_4$ | 7.09 | (49.33) | 8.38 | (69.33) | 7.46 | (54.67) |
| $s_1w_5$ | 5.20 | (29.67) | 6.08 | (36.00) | 5.55 | (29.67) |
| $s_1w_6$ | 5.54 | (29.33) | 6.39 | (40.00) | 4.99 | (24.00) |
| $s_1w_7$ | 7.36 | (53.33) | 8.39 | (69.33) | 6.39 | (40.00) |
| $s_1w_8$ | 10.49 | (109.33) | 10.63 | (112.00) | 9.22 | (84.00) |
| $s_2w_1$ | 7.00 | (48.00) | 7.09 | (49.33) | 4.58 | (20.00) |
| $s_2w_2$ | 6.80 | (45.33) | 8.30 | (68.00) | 4.99 | (24.00) |
| $s_2w_3$ | 7.28 | (52.00) | 5.50 | (29.33) | 4.72 | (21.33) |
| $s_2w_4$ | 6.61 | (42.67) | 11.24 | (125.33) | 7.71 | (58.67) |
| $s_2w_5$ | 7.81 | (60.0) | 6.51 | (41.33) | 5.63 | (30.67) |
| $s_2w_6$ | 7.00 | (48.00) | 8.54 | (72.00) | 7.42 | (54.00) |
| $s_2w_7$ | 7.79 | (62.67) | 9.64 | (92.00) | 5.49 | (29.33) |
| $s_2w_8$ | 14.85 | (220.00) | 13.25 | (174.67) | 11.24 | (126.00) |
| SE m (±) | 0.58 | | 0.22 | | 0.28 | |
| CD (0.05) | 1.67 | | 0.64 | | 0.82 | |

Values in parentheses are original values, data are subjected to square root transformation $\sqrt{(x+1)}$.

Interaction effect was significant at all the three stages of observation. At 15 DAS, $s_1w_3$ recorded the lowest relative density of grasses and the highest in $s_2w_5$. However, at 30 DAS the lowest relative density of grasses was observed in $s_2w_8$ and the highest in $s_1w_5$ and at 45 DAS the lowest relative density of grasses was observed in $s_2w_2$ and the highest in $s_1w_1$.

**4.7.7 Relative Density of BLW (Table 22, 22a, 23, 23a, 24 and 24a)**

Relative density of BLW was significantly influenced by seed bed preparation only at 30 and 45 DAS. Stale seed bed recorded the lowest values at 30 and 45 DAS (37.22 and 32.16 per cent, respectively).

Weed management practices also significantly influenced the relative density of BLW at all the three stages of observation. At 15 and 30 DAS, $W_5$ recorded the lowest value and at 45 DAS, $W_3$ recorded the lowest value.

Interaction effect also had significant influence on relative density of BLW at 15, 30 and 45 DAS. At 15 DAS, $s_2w_5$ recorded the lowest value, however at 30 DAS, $s_1w_5$ and at 45 DAS, $s_1w_3$ recorded the lowest value.

**4.7.8 Relative Density of Sedges (Table 22, 22a, 23, 23a, 24 and 24a)**

Seed bed preparation had significant effect on relative density of sedges only at 15 DAS. Normal seed bed recorded the lowest relative density of sedges (3.06 per cent) compared to SSB.

Weed management practices had significant effect on relative density of sedges only at 15 and 45 DAS. At 15 DAS, $W_4$ and $W_1$ recorded zero relative density of sedges and at 45 DAS, $W_1$, $W_2$ and $W_8$ recorded zero relative density of sedges.

Interaction effect also significantly influenced the relative density of sedges at 15 DAS and at 45 DAS. The treatment combinations, $s_1w_1$, $s_1w_4$, $s_1w_7$, $s_1w_8$, $s_2w_1$, $s_2w_2$, $s_2w_4$ and $s_2w_6$ recorded zero relative density of sedges at 15 DAS and at 45 DAS, all treatment combinations except $s_1w_3$, $s_1w_5$, $s_2w_4$, $s_2w_5$, $s_2w_7$ and $s_2w_8$ recorded zero relative density of sedges.

### 4.7.9 Total Weed Dry Weight (Table 25 and Table 25a)

Manipulation of seed bed preparation resulted in significantly lower total weed dry weight in SSB compared to normal seed bed at 15, 30 and 45 DAS.

Data revealed that between the weed management practices $W_6$ recorded the lowest total weed dry weight (0.24 g $m^{-2}$) at 15 DAS which was statistically comparable with all treatments except $W_7$ and $W_8$. At 30 DAS, $W_7$ recorded the lowest total weed dry weight which was statistically comparable with all treatments except $W_4$ and $W_8$. At 45 DAS $W_3$ recorded the lowest total weed dry weight which was statistically comparable with $W_5$.

Interaction effect also had significant impact on total weed dry weight at all the three stages of observation. At 15 DAS, $s_1w_6$ recorded the lowest weed dry weight which was statistically at par with the treatment combinations except $s_2w_4$, $s_2w_7$, $s_1w_8$ and $s_2w_8$. At 30 DAS, $s_1w_7$ treatment combination noted the lowest weed dry weight which was statistically on par with the treatments other than $s_1w_4$, $s_2w_1$, $s_2w_2$, $s_2w_3$, $s_2w_4$ and $s_2w_8$. However, at 45 DAS $s_1w_6$ recorded the lowest total weed dry weight which was statistically on par with $s_1w_5$ and $s_1w_3$.

### 4.7.10 Weed Control Efficiency (WCE) (Table 26 and 26a)

Weed control efficiency was significantly influenced by seed bed preparation. At 15, 30 and 45 DAS, SSB recorded significantly higher WCE of 79.05, 83.45 and 82.13 per cent, respectively compared to normal seed bed which recorded the WCE of 66.35, 72.43 and 67.60 per cent, respectively.

Weed management practices also significantly influenced the WCE at 15, 30 and 45 DAS. At 15 DAS, $W_6$ recorded the highest WCE which was statistically on par with all weed management treatments except, $W_7$. At 30 DAS also, $W_7$ recorded the highest WCE which was on par with all weed management treatments except, $W_4$. However, at 45 DAS, $W_3$ recorded the highest WCE which was statistically on par with all weed management treatments except $W_4$ and $W_1$.

Interaction effect was significant. The treatment combination, $s_1w_6$ recorded the highest WCE of 89.32 per cent at 15 DAS which was comparable with all treatments except, $s_2w_7$ and $s_1w_8$. At 30 DAS, $s_1w_7$ registered the highest WCE and it was on par with

Table 22. Effect of seed bed preparation and weed management practices on relative density (Rd) of weeds at 15 DAS

| Treatments | Grasses (%) | | Sedges (%) | | BLW (%) | |
|---|---|---|---|---|---|---|
| Seed bed preparation (S) | | | | | | |
| $S_1$ | 7.47 | (54.73) | 2.40 | (4.78) | 6.44 | (40.48) |
| $S_2$ | 7.59 | (56.60) | 2.01 | (3.06) | 6.43 | (40.34) |
| SE m (±) | 0.05 | | 0.02 | | 0.06 | |
| CD (0.05) | NS | | 0.06 | | NS | |
| Weed management practices (W) | | | | | | |
| $W_1$ | 7.58 | (56.45) | 1.00 | (0.00) | 6.67 | (43.55) |
| $W_2$ | 7.58 | (56.42) | 1.97 | (2.90) | 6.46 | (40.68) |
| $W_3$ | 6.80 | (45.21) | 3.94 | (14.52) | 6.42 | (40.26) |
| $W_4$ | 7.26 | (51.71) | 1.00 | (0.00) | 6.95 | (47.29) |
| $W_5$ | 7.90 | (61.46) | 2.67 | (6.14) | 5.78 | (32.40) |
| $W_6$ | 7.68 | (58.05) | 1.94 | (2.78) | 6.34 | (39.17) |
| $W_7$ | 7.28 | (52.03) | 2.40 | (4.76) | 6.65 | (43.21) |
| $W_8$ | 8.00 | (63.00) | 1.13 | (0.27) | 6.14 | (36.73) |
| SE m (±) | 0.09 | | 0.04 | | 0.12 | |
| CD (0.05) | 0.27 | | 0.12 | | 0.33 | |

Values in parentheses are original values, data are subjected to square root transformation $\sqrt{(x+1)}$, NS: non-significant

Table 22a. Interaction effect of seed bed preparation and weed management practices on relative density (Rd) of weeds at 15 DAS

| Treatments | Grasses (%) | | Sedges (%) | | BLW (%) | |
|---|---|---|---|---|---|---|
| $s_1w_1$ | 8.11 | (64.74) | 1.00 | (0.00) | 6.02 | (35.26) |
| $s_1w_2$ | 7.55 | (55.94) | 2.61 | (5.80) | 6.26 | (38.26) |
| $s_1w_3$ | 6.55 | (41.94) | 4.48 | (19.04) | 6.32 | (39.02) |
| $s_1w_4$ | 7.06 | (48.89) | 1.00 | (0.00) | 7.22 | (51.11) |
| $s_1w_5$ | 7.17 | (50.39) | 2.97 | (7.85) | 6.54 | (41.76) |
| $s_1w_6$ | 7.33 | (52.78) | 2.56 | (5.55) | 6.53 | (41.67) |
| $s_1w_7$ | 7.79 | (59.62) | 1.00 | (0.00) | 6.43 | (40.39) |
| $s_1w_8$ | 8.04 | (63.60) | 1.00 | (0.00) | 6.12 | (36.40) |
| $s_2w_1$ | 7.02 | (48.15) | 1.00 | (0.00) | 7.27 | (51.85) |
| $s_2w_2$ | 7.61 | (56.90) | 1.00 | (0.00) | 6.64 | (43.10) |
| $s_2w_3$ | 7.03 | (48.49) | 3.32 | (10.00) | 6.52 | (41.51) |
| $s_2w_4$ | 7.57 | (56.53) | 1.00 | (0.00) | 6.66 | (43.47) |
| $s_2w_5$ | 8.57 | (72.53) | 2.35 | (4.53) | 4.90 | (23.03) |
| $s_2w_6$ | 8.02 | (63.32) | 1.00 | (0.00) | 6.14 | (36.68) |
| $s_2w_7$ | 6.74 | (44.44) | 3.24 | (9.52) | 6.86 | (46.04) |
| $s_2w_8$ | 7.96 | (62.40) | 1.24 | (0.54) | 6.17 | (37.05) |
| SE m (±) | 0.13 | | 0.06 | | 0.16 | |
| CD (0.05) | 0.38 | | 0.17 | | 0.47 | |

Values in parentheses are original values, data are subjected to square root transformation $\sqrt{(x+1)}$

Table 23. Effect of seed bed preparation and weed management practices on relative density (Rd) of weeds at 30 DAS

| Treatments | Grasses (%) | | Sedges (%) | BLW (%) | |
|---|---|---|---|---|---|
| Seed bed preparation (S) | | | | | |
| $S_1$ | 7.98 | (62.77) | 0.00 | 6.18 | (37.22) |
| $S_2$ | 7.26 | (51.67) | 0.00 | 7.02 | (48.33) |
| SE m (±) | 0.11 | | - | 0.19 | |
| CD (0.05) | 0.32 | | - | 0.55 | |
| Weed management practices (W) | | | | | |
| $W_1$ | 6.89 | (46.54) | 0.00 | 7.38 | (53.46) |
| $W_2$ | 7.63 | (57.21) | 0.00 | 6.62 | (42.79) |
| $W_3$ | 8.32 | (68.18) | 0.00 | 5.73 | (31.81) |
| $W_4$ | 7.77 | (59.35) | 0.00 | 6.45 | (40.65) |
| $W_5$ | 8.68 | (74.30) | 0.00 | 5.17 | (25.70) |
| $W_6$ | 7.65 | (57.57) | 0.00 | 6.59 | (42.43) |
| $W_7$ | 7.76 | (59.28) | 0.00 | 6.46 | (40.72) |
| $W_8$ | 6.03 | (35.34) | 0.00 | 8.10 | (64.65) |
| SE m (±) | 0.22 | | - | 0.38 | |
| CD (0.05) | 0.63 | | - | 1.10 | |

Values in parentheses are original values, data are subjected to square root transformation $\sqrt{(x+1)}$

Table 23a. Interaction effect of seed bed preparation and weed management practices on relative density (Rd) of weeds at 30 DAS

| Treatments | Grasses (%) | | Sedges (%) | BLW (%) | |
|---|---|---|---|---|---|
| $s_1w_1$ | 6.97 | (47.63) | 0.00 | 7.31 | (52.37) |
| $s_1w_2$ | 8.83 | (77.01) | 0.00 | 4.90 | (22.99) |
| $s_1w_3$ | 8.66 | (73.95) | 0.00 | 5.20 | (26.05) |
| $s_1w_4$ | 8.16 | (65.55) | 0.00 | 5.95 | (34.45) |
| $s_1w_5$ | 8.86 | (77.55) | 0.00 | 4.84 | (22.45) |
| $s_1w_6$ | 8.24 | (67.04) | 0.00 | 5.83 | (32.96) |
| $s_1w_7$ | 7.26 | (51.85) | 0.00 | 7.01 | (48.15) |
| $s_1w_8$ | 6.53 | (41.64) | 0.00 | 7.70 | (58.36) |
| $s_2w_1$ | 6.82 | (45.45) | 0.00 | 7.45 | (54.54) |
| $s_2w_2$ | 6.20 | (37.40) | 0.00 | 7.97 | (62.59) |
| $s_2w_3$ | 7.96 | (62.41) | 0.00 | 6.21 | (37.58) |
| $s_2w_4$ | 7.36 | (53.16) | 0.00 | 6.92 | (46.84) |
| $s_2w_5$ | 8.49 | (71.06) | 0.00 | 5.47 | (28.93) |
| $s_2w_6$ | 7.01 | (48.10) | 0.00 | 7.27 | (51.90) |
| $s_2w_7$ | 8.23 | (66.70) | 0.00 | 5.86 | (33.30) |
| $s_2w_8$ | 5.48 | (29.04) | 0.00 | 8.48 | (70.96) |
| SE m (±) | 0.31 | | - | 0.54 | |
| CD (0.05) | 0.89 | | - | 1.55 | |

Values in parentheses are original values, data are subjected to square root transformation $\sqrt{(x+1)}$

Table 24. Effect of seed bed preparation and weed management practices on relative density (Rd) of weeds at 45 DAS

| Treatments | Grasses (%) | | Sedges (%) | | BLW (%) | |
|---|---|---|---|---|---|---|
| Seed bed preparation (S) | | | | | | |
| $S_1$ | 8.14 | (65.21) | 1.91 | (2.63) | 5.76 | (32.16) |
| $S_2$ | 7.33 | (52.80) | 1.63 | (1.66) | 6.82 | (45.54) |
| SE m (±) | 0.08 | | 0.10 | | 0.18 | |
| CD (0.05) | 0.24 | | NS | | 0.53 | |
| Weed management practices (W) | | | | | | |
| $W_1$ | 8.75 | (75.53) | 1.00 | (0.00) | 5.07 | (24.67) |
| $W_2$ | 7.17 | (50.42) | 1.00 | (0.00) | 7.11 | (49.58) |
| $W_3$ | 8.65 | (73.80) | 2.17 | (3.70) | 4.85 | (22.49) |
| $W_4$ | 7.75 | (59.08) | 1.81 | (2.27) | 6.30 | (38.65) |
| $W_5$ | 7.19 | (50.71) | 3.17 | (9.06) | 6.42 | (40.24) |
| $W_6$ | 6.55 | (41.86) | 1.00 | (0.00) | 7.69 | (58.14) |
| $W_7$ | 8.24 | (66.98) | 1.77 | (2.15) | 5.65 | (30.87) |
| $W_8$ | 7.41 | (53.85) | 0.00 | (0.00) | 6.87 | (46.15) |
| SE m (±) | 0.17 | | 0.21 | | 0.37 | |
| CD (0.05) | 0.49 | | 0.60 | | 1.06 | |

Values in parentheses are original values, data are subjected to square root transformation $\sqrt{(x+1)}$, NS: non-significant

Table 24a. Interaction effect of seed bed preparation and weed management practices on relative density (Rd) of weeds at 45 DAS

| Treatments | Grasses (%) | | Sedges (%) | | BLW (%) | |
|---|---|---|---|---|---|---|
| $s_1w_1$ | 9.56 | (90.47) | 1.00 | (0.00) | 3.24 | (9.52) |
| $s_1w_2$ | 7.95 | (62.22) | 1.00 | (0.00) | 6.23 | 37.78) |
| $s_1w_3$ | 9.28 | (85.19) | 2.90 | (7.41) | 2.90 | (7.41) |
| $s_1w_4$ | 8.18 | (65.93) | 0.71 | (0.00) | 5.92 | (34.07) |
| $s_1w_5$ | 6.77 | (44.86) | 3.83 | (13.65) | 6.52 | (41.49) |
| $s_1w_6$ | 6.72 | (44.17) | 1.00 | (0.00) | 7.54 | (55.83) |
| $s_1w_7$ | 8.43 | (70.05) | 1.00 | (0.00) | 5.56 | (29.95) |
| $s_1w_8$ | 7.73 | (58.75) | 1.00 | (0.00) | 6.50 | (41.25) |
| $s_2w_1$ | 7.82 | (60.19) | 1.00 | (0.00) | 6.39 | (39.81) |
| $s_2w_2$ | 6.29 | (38.61) | 1.00 | (0.00) | 7.90 | (61.38) |
| $s_2w_3$ | 7.97 | (62.46) | 1.00 | (0.00) | 6.21 | (37.58) |
| $s_2w_4$ | 7.30 | (52.23) | 2.35 | (4.53) | 6.65 | (43.24) |
| $s_2w_5$ | 8.49 | (56.54) | 2.34 | (4.46) | 6.32 | (38.99) |
| $s_2w_6$ | 7.59 | (39.54) | 1.00 | (0.00) | 7.84 | (60.46) |
| $s_2w_7$ | 8.06 | (63.91) | 2.30 | (4.31) | 5.73 | (31.78) |
| $s_2w_8$ | 7.07 | (48.95) | 1.63 | (1.66) | 7.21 | (51.05) |
| SE m (±) | 0.24 | | 0.29 | | 0.52 | |
| CD (0.05) | 0.69 | | 0.85 | | 1.50 | |

Values in parentheses are original values, data are subjected to square root transformation $\sqrt{(x+1)}$

Table 25. Effect of seed bed preparation and weed management practices on total weed dry weight

| Treatments | Total weed dry weight (g $m^{-2}$) | | | | | |
|---|---|---|---|---|---|---|
| | 15 DAS | | 30 DAS | | 45 DAS | |
| Seed bed preparation | | | | | | |
| $S_1$ | 1.17 | (0.38) | 1.95 | (2.79) | 3.27 | (9.71) |
| $S_2$ | 1.26 | (0.61) | 2.37 | (4.65) | 4.31 | (17.58) |
| SE m (±) | 0.09 | | 0.08 | | 0.04 | |
| CD (0.05) | 0.04 | | 0.12 | | 0.11 | |
| Weed management practices | | | | | | |
| $W_1$ | 1.12 | (0.26) | 1.74 | (2.04) | 2.98 | (7.87) |
| $W_2$ | 1.13 | (0.28) | 1.67 | (1.78) | 2.59 | (5.70) |
| $W_3$ | 1.12 | (0.26) | 1.75 | (2.08) | 2.18 | (3.77) |
| $W_4$ | 1.18 | (0.40) | 2.59 | (5.69) | 5.39 | (28.09) |
| $W_5$ | 1.14 | (0.30) | 1.64 | (1.70) | 2.29 | (4.28) |
| $W_6$ | 1.11 | (0.24) | 1.59 | (1.52) | 2.61 | (5.80) |
| $W_7$ | 1.29 | (0.69) | 1.53 | (1.34) | 2.48 | (5.13) |
| $W_8$ | 1.58 | (1.51) | 3.82 | (13.61) | 7.04 | (48.53) |
| SE m (±) | 0.02 | | 0.08 | | 0.08 | |
| CD (0.05) | 0.07 | | 0.23 | | 0.22 | |

Values in parentheses are original values, data are subjected to square root transformation $\sqrt{(x+1)}$.

Table 25a. Interaction effect of seed bed preparation and weed management practices on total weed dry weight

| Treatments | Total weed dry weight (g m$^{-2}$) | | | | | |
|---|---|---|---|---|---|---|
| | 15 DAS | | 30 DAS | | 45 DAS | |
| $s_1w_1$ | 1.11 | (0.23) | 1.69 | (1.87) | 2.16 | (3.70) |
| $s_1w_2$ | 1.11 | (0.24) | 1.49 | (1.23) | 2.07 | (3.30) |
| $s_1w_3$ | 1.11 | (0.24) | 1.64 | (1.70) | 1.87 | (2.50) |
| $s_1w_4$ | 1.1 | (0.32) | 2.15 | (3.63) | 4.29 | (17.43) |
| $s_1w_5$ | 1.12 | (0.26) | 1.57 | (1.47) | 1.67 | (1.77) |
| $s_1w_6$ | 1.09 | (0.19) | 1.49 | (1.22) | 1.62 | (1.32) |
| $s_1w_7$ | 1.15 | (0.33) | 1.44 | (1.08) | 2.42 | (4.89) |
| $s_1w_8$ | 1.49 | (1.21) | 3.33 | (10.11) | 6.60 | (42.70) |
| $s_2w_1$ | 1.13 | (0.28) | 1.79 | (2.20) | 3.61 | (12.01) |
| $s_2w_2$ | 1.15 | (0.32) | 1.82 | (2.33) | 3.02 | (8.09) |
| $s_2w_3$ | 1.13 | (0.29) | 1.86 | (2.46) | 2.45 | (5.03) |
| $s_2w_4$ | 1.21 | (0.48) | 2.96 | (7.74) | 6.30 | (38.75) |
| $s_2w_5$ | 1.16 | (0.34) | 1.71 | (1.93) | 2.79 | (6.79) |
| $s_2w_6$ | 1.13 | (0.29) | 1.68 | (1.83) | 3.36 | (10.28) |
| $s_2w_7$ | 1.43 | (1.06) | 1.60 | (1.61) | 2.52 | (5.37) |
| $s_2w_8$ | 1.68 | (1.81) | 4.26 | (17.11) | 7.44 | (54.35) |
| SE m (±) | 0.03 | | 0.11 | | 0.12 | |
| CD (0.05) | 0.10 | | 0.33 | | 0.34 | |

Values in parentheses are original values, data are subjected to square root transformation $\sqrt{(x+1)}$.

all treatment combinations, except $s_1w_4$, $s_2w_4$ and $s_1w_8$. However, at 45 DAS, $s_1w_6$ recorded the highest WCE which was statistically on par with all treatment combinations except $s_2w_3$, $s_2w_7$, $s_2w_5$, $s_2w_2$, $s_2w_6$, $s_1w_4$, $s_2w_4$ and $s_1w_8$.

## 4.8 SOIL ANALYSIS

### 4.8.1 Soil Organic Carbon Content (Table 27 and 27a)

Soil organic carbon content was not significantly influenced by seed bed preparation. Although stale seed bed recorded the highest organic carbon of 0.97 per cent as against normal seed bed which recorded the soil organic carbon content of 0.96 per cent.

Weed management practices also significantly influenced the soil organic carbon content. Among the weed management practices, $W_2$ recorded the highest per cent of soil organic carbon (1.072 per cent) and it was on par with all treatments except $W_4$ and $W_8$. The soil organic carbon content was the lowest in weedy check (0.842 per cent).

Interaction effect had no significant influence on soil organic carbon content.

### 4.8.2 Available Soil Nitrogen (Table 27 and 27a)

Available soil N was also significantly influenced by both seed bed preparation and weed management practices. Stale seed bed recorded the highest available soil N of 286.59 kg ha$^{-1}$ whereas, normal seed bed recorded available soil N of 265.50 kg ha$^{-1}$.

With respect to weed management practices, the highest available soil N of 367.92 kg ha$^{-1}$ was recorded in $W_3$ which was on par with $W_2$ and $W_1$. Weedy check recorded the lowest available soil N.

Interaction effect had no significant influence on available soil N.

### 4.8.3 Available Soil Phosphorus (Table 27 and 27a)

Available soil P was also influenced by seed bed manipulation and weed management practices. Compared to normal seed bed preparation, SSB recorded the highest available P in soil (39.31 kg ha$^{-1}$).

Table 26. Effect of seed bed preparation and weed management practices on weed control efficiency (WCE)

| Treatments | WCE (%) | | |
|---|---|---|---|
| | 15 DAS | 30 DAS | 45 DAS |
| Seed bed preparation | | | |
| $S_1$ | 8.89 (79.05) | 9.14 (83.45) | 9.06 (82.13) |
| $S_2$ | 8.15 (66.35) | 8.51 (72.43) | 8.22 (67.60) |
| SE m (±) | 0.12 | 0.05 | 0.04 |
| CD (0.05) | 0.34 | 0.15 | 0.12 |
| Weed management practices | | | |
| $W_1$ | 9.26 (85.81) | 9.37 (87.89) | 9.25 (85.50) |
| $W_2$ | 9.19 (84.50) | 9.46 (89.42) | 9.46 (89.43) |
| $W_3$ | 9.25 (85.65) | 9.37 (87.89) | 9.65 (93.05) |
| $W_4$ | 8.83 (77.95) | 8.12 (65.95) | 6.95 (48.27) |
| $W_5$ | 9.13 (83.30) | 9.46 (89.46) | 9.60 (92.08) |
| $W_6$ | 9.30 (86.55) | 9.52 (90.70) | 9.45 (89.27) |
| $W_7$ | 7.83 (61.45) | 9.59 (92.01) | 9.52 (90.54) |
| $W_8$ | 4.05 (16.37) | 4.49 (20.17) | 3.29 (10.80) |
| SE m (±) | 0.23 | 0.10 | 0.08 |
| CD (0.05) | 0.68 | 0.29 | 0.24 |

Values in parentheses are original values, data are subjected to square root transformation $\sqrt{(x)}$.

Table 26a. Interaction effect of seed bed preparation and weed management practices on weed control efficiency (WCE)

| Treatments | WCE (%) | | | | | |
|---|---|---|---|---|---|---|
| | 15 DAS | | 30 DAS | | 45 DAS | |
| $s_1w_1$ | 9.32 | (86.95) | 9.43 | (88.90) | 9.65 | (93.13) |
| $s_1w_2$ | 9.31 | (86.75) | 9.64 | (92.87) | 9.69 | (93.88) |
| $s_1w_3$ | 9.32 | (86.91) | 9.49 | (90.06) | 9.77 | (95.37) |
| $s_1w_4$ | 9.06 | (82.10) | 8.84 | (78.07) | 8.24 | (67.87) |
| $s_1w_5$ | 9.25 | (85.62) | 9.54 | (90.92) | 9.83 | (96.68) |
| $s_1w_6$ | 9.45 | (89.32) | 9.63 | (92.74) | 9.88 | (97.54) |
| $s_1w_7$ | 9.06 | (82.01) | 9.68 | (93.70) | 9.54 | (90.99) |
| $s_1w_8$ | 5.72 | (32.74) | 6.35 | (40.34) | 4.65 | (21.60) |
| $s_2w_1$ | 9.20 | (84.67) | 9.32 | (86.88) | 8.82 | (77.87) |
| $s_2w_2$ | 9.07 | (82.25) | 9.27 | (85.98) | 9.22 | (84.99) |
| $s_2w_3$ | 9.19 | (84.39) | 9.26 | (85.71) | 9.52 | (90.72) |
| $s_2w_4$ | 8.59 | (73.80) | 7.34 | (53.83) | 5.35 | (28.66) |
| $s_2w_5$ | 8.99 | (80.98) | 9.38 | (88.01) | 9.35 | (87.47) |
| $s_2w_6$ | 9.15 | (83.79) | 9.42 | (88.67) | 9.00 | (81.00) |
| $s_2w_7$ | 6.39 | (40.89) | 9.50 | (90.33) | 9.49 | (90.10) |
| $s_2w_8$ | 0.0 | (0.00) | 0.0 | ( 0.00) | 0.0 | (0.00) |
| SE m (±) | 0.33 | | 0.14 | | 0.12 | |
| CD (0.05) | 0.95 | | 0.41 | | 0.34 | |

Values in parentheses are original values, data are subjected to square root transformation $\sqrt{(x)}$

Among the weed management treatments, $W_1$ recorded the highest available soil P (42.85 kg $ha^{-1}$) which was on par with $W_2$, $W_3$ and $W_7$. Weedy check recorded the lowest available soil P.

Interaction effect had significant impact on available soil P. The treatment combination, $s_1w_1$ recorded the highest amount of available P in soil which was on par with $s_1w_2$. The treatment combination $s_1w_2$ was statistically comparable with $s_1w_7$, $s_2w_3$ and $s_1w_3$. The lowest available soil P was registered in $s_2w_8$.

**4.8.4 Available Soil Potassium (Table 27 and 27a)**

Similar to that of available N and P seed bed preparation and weed management practices had significant impact on available soil K. Stale seed bed recorded the highest available soil K of 105.74 kg $ha^{-1}$ as against normal seed bed which recorded an available soil K of 83.74 kg $ha^{-1}$.

Among the weed management practices $W_2$ recorded the highest available soil K of 118.02 kg $ha^{-1}$ which was on par with $W_3$ and the lowest soil available K was recorded in weedy check ($W_8$).

Interaction effect had significant influence on available soil K and the treatment combination $s_2w_2$ recorded the highest available soil K which was on par with $s_1w_3$ and $s_1w_6$ and the lowest was recorded in $s_2w_8$.

4.9. PLANT ANALYSIS

**4.9.1 Nutrient Uptake by Crop**

Crop uptake of N, P and K at harvest stage are presented in the Tables 31, 31a, 32, 32a, 33 and 33a

***4.9.1.1 Nitrogen Uptake by Crop (Table 28 and 28a)***

Seed bed preparation had significant effect on N uptake by pod and total N uptake by plant; however, N uptake by haulm was not significantly influenced by seed bed preparation. Compared to normal seed bed, SSB registered significantly higher N uptake by pod (50.61 kg $ha^{-1}$) and total N uptake (154.64 kg $ha^{-1}$).

Table 27. Effect of seed bed preparation and weed management practices on organic carbon, available soil N, P and K of post experiment soil

| Treatments | OC (%) | Available Soil N (kg ha$^{-1}$) | Available Soil P (kg ha$^{-1}$) | Available Soil K (kg ha$^{-1}$) |
|---|---|---|---|---|
| Seed bed preparation (S) | | | | |
| $S_1$ | 0.970 | 286.59 | 39.31 | 105.74 |
| $S_2$ | 0.961 | 265.50 | 36.71 | 83.74 |
| SE m (±) | 0.024 | 5.64 | 0.68 | 1.60 |
| CD (0.05) | NS | 16.37 | 1.96 | 4.65 |
| Weed management practices (W) | | | | |
| $W_1$ | 1.010 | 338.67 | 42.85 | 106.10 |
| $W_2$ | 1.072 | 355.37 | 41.64 | 118.02 |
| $W_3$ | 1.050 | 367.92 | 40.35 | 112.91 |
| $W_4$ | 0.907 | 255.07 | 34.81 | 81.92 |
| $W_5$ | 0.928 | 242.44 | 34.07 | 83.51 |
| $W_6$ | 0.977 | 255.03 | 37.92 | 105.38 |
| $W_7$ | 0.940 | 222.43 | 39.85 | 81.32 |
| $W_8$ | 0.842 | 171.43 | 32.54 | 68.77 |
| SE m (±) | 0.052 | 11.28 | 1.36 | 3.20 |
| CD (0.05) | 0.151 | 32.74 | 3.93 | 9.29 |

NS: non-significant

Table 27a. Interaction effect of seed bed preparation and weed management practices on organic carbon, available soil N, P and K of post experiment soil

| Treatments | OC (%) | Available Soil N (kg ha$^{-1}$) | Available Soil P (kg ha$^{-1}$) | Available Soil K (kg ha$^{-1}$) |
|---|---|---|---|---|
| $s_1w_1$ | 1.037 | 342.83 | 47.45 | 113.64 |
| $s_1w_2$ | 1.040 | 367.87 | 45.77 | 134.00 |
| $s_1w_3$ | 1.070 | 376.24 | 40.32 | 130.82 |
| $s_1w_4$ | 0.923 | 250.92 | 32.74 | 90.76 |
| $s_1w_5$ | 0.927 | 250.76 | 34.76 | 95.79 |
| $s_1w_6$ | 1.000 | 267.56 | 38.18 | 124.43 |
| $s_1w_7$ | 0.927 | 235.82 | 40.92 | 85.83 |
| $s_1w_8$ | 0.837 | 200.72 | 34.29 | 70.64 |
| $s_2w_1$ | 0.983 | 334.51 | 38.25 | 98.56 |
| $s_2w_2$ | 1.103 | 342.87 | 37.50 | 102.03 |
| $s_2w_3$ | 1.030 | 359.59 | 40.37 | 95.00 |
| $s_2w_4$ | 0.890 | 259.22 | 36.89 | 73.09 |
| $s_2w_5$ | 0.930 | 234.13 | 33.37 | 71.23 |
| $s_2w_6$ | 0.953 | 242.50 | 37.66 | 86.32 |
| $s_2w_7$ | 0.953 | 209.05 | 38.79 | 76.80 |
| $s_2w_8$ | 0.847 | 142.15 | 30.80 | 66.89 |
| SE m (±) | 0.069 | 15.95 | 1.92 | 4.53 |
| CD (0.05) | NS | NS | 5.56 | 13.14 |

NS: non-significant

Uptake of N by pod and haulm and total N uptake was significantly influenced by weed management practices. Among the weed management practices, $W_3$ recorded the highest N uptake by pod, haulm and total N uptake by crop compared to other treatments. Weedy check recorded significantly lower N uptake by pod, haulm and total N uptake among the treatments.

Interaction effect had no significant influence on N uptake by pod and total N uptake but had significant effect on N uptake by haulm and the treatment combination $s_1w_3$ recorded the highest N uptake by haulm which was statistically comparable with $s_2w_5$ and $s_1w_7$.

***4.9.1.2 Phosphorus Uptake by Crop (Table 29 and 29a)***

The result revealed that seed bed preparation significantly influenced the P uptake by pod, haulm, and the total P uptake by crop. Stale seed bed method accounted for the highest P uptake by pods (10.30 kg $ha^{-1}$), haulm (23.36 kg $ha^{-1}$) and total P uptake (33.66 kg $ha^{-1}$) by crop.

P uptake was significantly influenced by weed management practices. The treatment, $W_3$ recorded the highest uptake by pods which was significantly superior to other treatments. While, $W_6$ recorded the highest uptake by haulm, was statistically on par with $W_3$. With respect to total P uptake $W_3$ recorded the highest uptake and was significantly superior to other weed management practices. Weedy check ($W_8$) recorded the lowest P uptake by pod, haulm and total uptake by crop

The interaction effect was significant for P uptake by pod and haulm and total P uptake. Among the treatment combination, $s_1w_3$ recorded the highest P uptake by pod (14.71 kg $ha^{-1}$), haulm (29.94 kg $ha^{-1}$) and total P uptake (44.65 kg $ha^{-1}$). However, P uptake by pod was on par with $s_1w_2$ and P uptake by haulm was on par with $s_1w_6$ and $s_1w_7$.

***4.9.1.2 Potassium Uptake by Crop (Table 30 and 30a)***

Total K uptake by crop, K uptake by pod and haulm were significantly influenced by seed bed preparation. Stale seed bed recorded significantly higher total K uptake (40.30 kg $ha^{-1}$), uptake by pod (7.26 kg $ha^{-1}$) and uptake by haulm (33.04 kg $ha^{-1}$) compared to normal seed bed.

Between weed management practices, $W_3$ recorded the highest uptake by pod (8.30 kg ha$^{-1}$) and was statistically on par with $W_1$ and $W_2$. However, $W_6$ recorded the highest uptake by haulm and was statistically on par with $W_5$ and $W_1$. The total K uptake was also the highest in $W_6$ which was statistically on par with other weed management treatments except, $W_7$, $W_4$ and $W_8$.

Among the interaction effect, $s_2w_3$ recorded the highest K uptake by pod and was statistically on par with all treatment combinations, except $s_1w_7$, $s_2w_7$, $s_2w_5$, $s_1w_4$, $s_2w_4$, $s_1w_8$ and $s_2w_8$. Potassium uptake by haulm was the highest under $s_1w_6$ treatment which was on par with all other treatment combinations except $s_2w_1$, $s_2w_2$, $s_2w_3$, $s_2w_7$, $s_1w_4$, $s_2w_4$ and $s_1w_8$. The total K uptake was the highest under the treatment $s_1w_6$ and was statistically comparable with $s_1w_1$, $s_1w_5$, $s_1w_3$, $s_1w_2$ and $s_1w_7$.

**4.9.2. Nutrient Uptake by Weeds**

Nutrient uptake by weeds at 30 and 45 DAS are presented in Table 31, 31a, 32 and 32a.

***4.9.2.1 Nitrogen Uptake by Weeds***

N uptake by weeds was significantly influenced by seed bed preparation at 30 and 45 DAS. Stale seed bed recorded the lowest N uptake by weeds (2.211 and 9.616 kg ha$^{-1}$, respectively) which was significantly superior to normal seed bed which recorded the N uptake by weeds of 2.954 and 18.830 kg ha$^{-1}$, respectively at 30 and 45 DAS.

Weed management practices also had significant effect on N uptake by weeds. Weedy check ($W_8$) recorded the highest removal of 9.156 kg ha$^{-1}$ at 30 DAS and 53.386 kg ha$^{-1}$ at 45 DAS. The lowest N uptake at 30 DAS was recorded in $W_7$ which was significantly superior to other treatments. However, at 45 DAS, $W_3$ recorded the lowest N uptake by weeds which were statistically on par with $W_5$, $W_7$, $W_6$ and $W_2$.

Interaction effect was significant at both 30 and 45 DAS. At 30 DAS, $s_1w_7$ which was statistically on par with $s_2w_6$, $s_2w_7$ and $s_1w_2$. However, at 45 DAS the lowest N uptake by weeds was recorded in the treatment combination $s_1w_6$ which was statistically at par with $s_1w_5$, $s_1w_3$, $s_1w_1$ and $s_1w_2$. Among the treatment combination $s_2w_8$ recorded the highest

N uptake (11.740 and 64.590 kg ha$^{-1}$, respectively) and was significantly superior over other treatments.

### *4.9.2.2 Phosphorus Uptake by Weeds*

Phosphorus uptake by weeds was significantly influenced by seed bed preparation. Stale seed bed method accounted for the lowest P uptake by weeds at 30 and 45 DAS (0.218 and 0.736 kg ha$^{-1}$, respectively) compared to normal seed bed.

Phosphorus uptake by weeds was favorably influenced by weed management practices. Weedy check ($W_8$) recorded the highest P uptake by weeds both at 30 and 45 DAS (1.211 and 4.226 kg ha$^{-1}$, respectively). The P uptake was the lowest in $W_7$ at 30 DAS which was statistically comparable with $W_5$ and $W_3$. However, at 45 DAS the lowest P uptake was recorded by the treatment $W_3$ which was statistically at par with $W_7$ and $W_5$.

Interaction effect had significant impact on P uptake by weeds at 30 and 45 DAS. The lowest P uptake by weeds was recorded in the treatment $s_1w_3$ and $s_1w_5$ at 30 DAS. However, at 45 DAS $s_1w_6$ recorded the lowest P uptake which was statistically comparable with $s_1w_3$ and $s_1w_7$. The highest P uptake of 1.489 and 5.095 kg ha$^{-1}$, respectively were recorded in the treatment combination $s_2w_8$ at both 30 and 45 DAS.

### *4.9.2.3 Potassium Uptake by Weeds*

Manipulation of seed bed had significant effect on K uptake by weeds at 30 and 45 DAS. Stale seed bed recorded significantly lower K uptake of 1.41 and 6.18 kg ha$^{-1}$, respectively at 30 and 45 DAS as compared to normal seed bed.

Weed management practices favorably influenced the K uptake by weeds at 30 and 45 DAS. Weedy check ($W_8$) recorded the highest uptake of 10.54 and 40.44 kg ha$^{-1}$ at both the time of observation. However, at 30 DAS, $W_7$ recorded the lowest K uptake by weeds which were statistically comparable with $W_6$, $W_2$ and $W_5$ at 45 DAS, $W_3$ recorded the lowest K uptake by weeds which was statistically comparable with $W_7$ and $W_5$.

Table 28. Effect of seed bed preparation and weed management practices on N uptake by bush type vegetable cow pea, kg $ha^{-1}$

| Treatments | N uptake by pod | N uptake by haulm | Total N uptake |
|---|---|---|---|
| Seed bed preparation (S) | | | |
| $S_1$ | 50.61 | 104.03 | 154.64 |
| $S_2$ | 37.21 | 100.29 | 137.50 |
| SE m (±) | 0.85 | 2.02 | 3.26 |
| CD (0.05) | 2.46 | NS | 9.45 |
| Weed management practices (W) | | | |
| $W_1$ | 61.37 | 99.63 | 161.01 |
| $W_2$ | 53.52 | 101.16 | 154.68 |
| $W_3$ | 63.56 | 117.74 | 181.30 |
| W4 | 26.79 | 89.07 | 115.87 |
| $W_5$ | 39.91 | 113.40 | 153.31 |
| $W_6$ | 44.41 | 109.77 | 154.18 |
| $W_7$ | 44.35 | 106.88 | 151.23 |
| $W_8$ | 17.39 | 79.63 | 97.01 |
| SE m (±) | 1.69 | 4.04 | 6.51 |
| CD (0.05) | 4.91 | 11.71 | 18.89 |

NS: non-significant

Table 28a. Interaction effect of seed bed preparation and weed management practices on N uptake by bush type vegetable cow pea, kg $ha^{-1}$

| Treatments | N uptake by pod | N uptake by haulm | Total N uptake |
|---|---|---|---|
| $s_1w_1$ | 71.34 | 105.12 | 176.46 |
| $s_1w_2$ | 61.07 | 108.12 | 169.19 |
| $s_1w_3$ | 70.66 | 130.29 | 200.95 |
| $s_1w_4$ | 28.83 | 84.57 | 113.39 |
| $s_1w_5$ | 45.88 | 101.63 | 147.51 |
| $s_1w_6$ | 52.07 | 107.09 | 159.16 |
| $s_1w_7$ | 52.50 | 115.57 | 163.01 |
| $s_1w_8$ | 22.54 | 84.94 | 107.47 |
| $s_2w_1$ | 51.41 | 94.15 | 145.56 |
| $s_2w_2$ | 45.96 | 94.20 | 140.16 |
| $s_2w_3$ | 56.46 | 105.20 | 161.66 |
| $s_2w_4$ | 24.76 | 93.58 | 118.34 |
| $s_2w_5$ | 33.93 | 125.17 | 159.11 |
| $s_2w_6$ | 36.75 | 112.46 | 149.20 |
| $s_2w_7$ | 36.19 | 103.25 | 139.44 |
| $s_2w_8$ | 12.24 | 74.31 | 86.56 |
| SE m (±) | 2.39 | 5.71 | 9.21 |
| CD (0.05) | NS | 16.57 | NS |

NS: non-significant

Table 29. Effect of seed bed preparation and weed management practices on P uptake by bush type vegetable cowpea, kg ha$^{-1}$

| Treatments | P uptake by pod | P uptake by haulm | Total P uptake |
|---|---|---|---|
| Seed bed preparation (S) | | | |
| $S_1$ | 10.30 | 23.36 | 33.66 |
| $S_2$ | 7.21 | 18.06 | 25.26 |
| SE m (±) | 0.27 | 0.44 | 0.54 |
| CD (0.05) | 0.78 | 1.29 | 1.56 |
| Weed management practices (W) | | | |
| $W_1$ | 10.59 | 21.43 | 32.02 |
| $W_2$ | 11.75 | 22.32 | 34.06 |
| $W_3$ | 13.21 | 25.46 | 38.67 |
| $W_4$ | 5.54 | 15.57 | 21.11 |
| $W_5$ | 9.59 | 21.52 | 31.11 |
| $W_6$ | 7.62 | 26.02 | 33.64 |
| $W_7$ | 9.25 | 21.82 | 31.06 |
| $W_8$ | 2.48 | 11.54 | 14.02 |
| SE m (±) | 0.53 | 0.89 | 1.07 |
| CD (0.05) | 1.55 | 2.58 | 3.11 |

Table 29a. Interaction effect of seed bed preparation and weed management practices on P uptake by bush type vegetable cow pea, kg ha$^{-1}$

| Treatments | P uptake by pod | P uptake by haulm | Total P uptake |
|---|---|---|---|
| $s_1w_1$ | 12.51 | 22.76 | 35.27 |
| $s_1w_2$ | 13.20 | 25.30 | 38.49 |
| $s_1w_3$ | 14.71 | 29.94 | 44.65 |
| $s_1w_4$ | 5.53 | 15.65 | 21.18 |
| $s_1w_5$ | 12.24 | 25.85 | 38.08 |
| $s_1w_6$ | 8.98 | 28.90 | 37.88 |
| $s_1w_7$ | 11.79 | 26.74 | 38.53 |
| $s_1w_8$ | 3.42 | 11.74 | 15.16 |
| $s_2w_1$ | 8.67 | 20.10 | 28.77 |
| $s_2w_2$ | 10.30 | 19.34 | 29.63 |
| $s_2w_3$ | 11.71 | 20.98 | 32.68 |
| $s_2w_4$ | 5.55 | 15.49 | 21.04 |
| $s_2w_5$ | 6.94 | 17.19 | 24.13 |
| $s_2w_6$ | 6.25 | 23.14 | 29.39 |
| $s_2w_7$ | 6.70 | 16.90 | 23.60 |
| $s_2w_8$ | 1.53 | 11.34 | 12.87 |
| SE m (±) | 0.76 | 1.26 | 1.52 |
| CD (0.05) | 2.19 | 3.64 | 4.40 |

Table 30. Effect of seed bed preparation and weed management practices on K uptake by bush type vegetable cowpea, kg $ha^{-1}$

| Treatments | K uptake by pod | K uptake by haulm | Total K uptake |
|---|---|---|---|
| Seed bed preparation (S) | | | |
| $S_1$ | 7.26 | 33.04 | 40.30 |
| $S_2$ | 6.27 | 30.81 | 37.07 |
| SE m (±) | 0.14 | 0.41 | 0.44 |
| CD (0.05) | 0.42 | 1.20 | 1.26 |
| Weed management practices (W) | | | |
| $W_1$ | 8.26 | 33.36 | 41.62 |
| $W_2$ | 7.95 | 32.44 | 40.39 |
| $W_3$ | 8.30 | 32.44 | 40.74 |
| $W_4$ | 5.37 | 27.99 | 33.36 |
| $W_5$ | 7.20 | 34.34 | 41.54 |
| $W_6$ | 6.89 | 34.96 | 41.85 |
| $W_7$ | 6.95 | 31.60 | 38.54 |
| $W_8$ | 3.20 | 28.24 | 31.45 |
| SE m (±) | 0.29 | 0.13 | 0.87 |
| CD (0.05) | 0.84 | 2.41 | 2.53 |

Table 30a. Interaction effect of seed bed preparation and weed management practices on K uptake by bush type vegetable cow pea, kg ha$^{-1}$

| Treatments | K uptake by pod | K uptake by haulm | Total K uptake |
|---|---|---|---|
| $s_1w_1$ | 8.49 | 35.43 | 43.91 |
| $s_1w_2$ | 7.98 | 33.98 | 41.96 |
| $s_1w_3$ | 8.07 | 34.43 | 42.50 |
| $s_1w_4$ | 5.98 | 28.30 | 34.28 |
| $s_1w_5$ | 8.00 | 35.44 | 43.45 |
| $s_1w_6$ | 8.07 | 36.51 | 44.58 |
| $s_1w_7$ | 7.07 | 34.57 | 41.64 |
| $s_1w_8$ | 4.42 | 25.66 | 30.09 |
| $s_2w_1$ | 8.03 | 3130 | 39.38 |
| $s_2w_2$ | 7.92 | 30.91 | 38.83 |
| $s_2w_3$ | 8.52 | 30.46 | 38.98 |
| $s_2w_4$ | 4.75 | 27.68 | 32.43 |
| $s_2w_5$ | 6.40 | 33.25 | 39.64 |
| $s_2w_6$ | 5.70 | 33.41 | 39.11 |
| $s_2w_7$ | 6.82 | 28.63 | 35.45 |
| $s_2w_8$ | 1.98 | 30.82 | 32.81 |
| SE m (±) | 0.48 | 1.17 | 1.23 |
| CD (0.05) | 1.19 | 3.40 | 3.57 |

Table 31. Effect of seed bed preparation and weed management practices on nutrient uptake by weeds at 30 DAS

| Treatments | Nutrient uptake (kg ha$^{-1}$) | | |
|---|---|---|---|
| | N uptake | P uptake | K uptake |
| Seed bed preparation (S) | | | |
| $S_1$ | 2.21 | 0.22 | 1.41 |
| $S_2$ | 2.95 | 0.37 | 3.68 |
| SE m (±) | 0.06 | 0.01 | 0.01 |
| CD (0.05) | 0.16 | 0.02 | 0.02 |
| Weed management practices (W) | | | |
| $W_1$ | 1.37 | 0.20 | 1.21 |
| $W_2$ | 1.31 | 0.15 | 1.04 |
| $W_3$ | 1.59 | 0.06 | 1.29 |
| $W_4$ | 3.72 | 0.54 | 3.54 |
| $W_5$ | 1.38 | 0.06 | 1.05 |
| $W_6$ | 1.28 | 0.09 | 0.92 |
| $W_7$ | 0.86 | 0.04 | 0.76 |
| $W_8$ | 9.16 | 1.21 | 10.54 |
| SE m (±) | 0.11 | 0.01 | 0.01 |
| CD (0.05) | 0.32 | 0.04 | 0.03 |

Table 31a. Interaction effect of seed bed preparation and weed management practices on nutrient uptake by weeds at 30 DAS

| Treatments | Nutrient uptake (kg ha$^{-1}$) | | |
|---|---|---|---|
| | N uptake | P uptake | K uptake |
| $s_1w_1$ | 1.18 | 0.15 | 1.22 |
| $s_1w_2$ | 1.03 | 0.10 | 0.57 |
| $s_1w_3$ | 1.58 | 0.03 | 1.01 |
| $s_1w_4$ | 3.56 | 0.41 | 1.16 |
| $s_1w_5$ | 1.54 | 0.03 | 0.01 |
| $s_1w_6$ | 1.54 | 0.07 | 0.58 |
| $s_1w_7$ | 0.68 | 0.03 | 0.50 |
| $s_1w_8$ | 6.57 | 0.93 | 6.27 |
| $s_2w_1$ | 1.55 | 0.26 | 1.19 |
| $s_2w_2$ | 1.58 | 0.19 | 1.52 |
| $s_2w_3$ | 1.61 | 0.09 | 1.58 |
| $s_2w_4$ | 3.87 | 0.67 | 5.91 |
| $s_2w_5$ | 1.23 | 0.08 | 2.09 |
| $s_2w_6$ | 1.02 | 0.12 | 1.27 |
| $s_2w_7$ | 1.03 | 0.04 | 1.02 |
| $s_2w_8$ | 11.74 | 1.49 | 14.81 |
| SE m (±) | 0.15 | 0.02 | 0.02 |
| CD (0.05) | 0.45 | 0.06 | 0.05 |

Table 32. Effect of seed bed preparation and weed management practices on nutrient uptake by weeds at 45 DAS

| Treatments | Nutrient uptake (kg ha$^{-1}$) | | |
|---|---|---|---|
| | N uptake | P uptake | K uptake |
| Seed bed preparation (S) | | | |
| $S_1$ | 9.62 | 0.74 | 6.18 |
| $S_2$ | 18.83 | 1.38 | 13.81 |
| SE m (±) | 0.36 | 0.02 | 0.025 |
| CD (0.05) | 1.05 | 0.06 | 0.074 |
| Weed management practices (W) | | | |
| $W_1$ | 8.20 | 0.68 | 4.82 |
| $W_2$ | 6.21 | 0.45 | 3.68 |
| $W_3$ | 4.22 | 0.16 | 2.17 |
| $W_4$ | 27.25 | 2.10 | 17.92 |
| $W_5$ | 4.28 | 0.27 | 3.60 |
| $W_6$ | 5.22 | 0.30 | 4.16 |
| $W_7$ | 5.03 | 0.27 | 3.19 |
| $W_8$ | 53.37 | 4.23 | 40.44 |
| SE m (±) | 0.72 | 0.04 | 0.51 |
| CD (0.05) | 2.09 | 0.13 | 0.15 |

Table 32a. Interaction effect of seed bed preparation and weed management practices on nutrient uptake by weeds at 45 DAS

| Treatments | Nutrient uptake (kg ha$^{-1}$) | | |
|---|---|---|---|
| | N uptake | P uptake | K uptake |
| $s_1w_1$ | 2.86 | 0.28 | 2.13 |
| $s_1w_2$ | 3.68 | 0.27 | 1.79 |
| $s_1w_3$ | 2.57 | 0.13 | 1.25 |
| $s_1w_4$ | 17.58 | 1.37 | 10.48 |
| $s_1w_5$ | 1.93 | 0.18 | 0.88 |
| $s_1w_6$ | 1.44 | 0.07 | 0.70 |
| $s_1w_7$ | 4.68 | 0.25 | 2.37 |
| $s_1w_8$ | 42.18 | 3.56 | 29.85 |
| $s_2w_1$ | 13.54 | 1.10 | 7.51 |
| $s_2w_2$ | 8.74 | 0.64 | 5.56 |
| $s_2w_3$ | 5.86 | 0.20 | 3.09 |
| $s_2w_4$ | 36.91 | 2.82 | 25.36 |
| $s_2w_5$ | 6.62 | 0.37 | 6.32 |
| $s_2w_6$ | 9.00 | 0.53 | 7.63 |
| $s_2w_7$ | 5.39 | 0.30 | 4.00 |
| $s_2w_8$ | 64.59 | 5.10 | 51.03 |
| SE m (±) | 1.02 | 0.06 | 0.07 |
| CD (0.05) | 2.96 | 0.18 | 0.21 |

Interaction effect had significant impact on K uptake by weeds. The lowest K uptake was observed by the treatment combination $s_1w_5$ at 30 DAS and $s_1w_6$ at 45 DAS. Among the treatment combination, $s_2w_8$ recorded the highest uptake of K at 30 and 45 DAS (14.81 and 51.03 kg $ha^{-1}$, respectively).

4.10 ENZYME ANALYSIS

**4.10.1 Dehydrogenase Enzyme Activity (Table 33 and 33a)**

Dehydrogenase enzyme activity was influenced by seed bed preparation significantly at all the three stages. At 15, 30 and 45 DAS, SSB recorded significantly higher dehydrogenase enzyme activity (3.82, 4.53 and 4.19 µg TPF $g^{-1}$ soil $day^{--1}$, respectively).

Weed management practices also had a favourable influence on dehydrogenase enzyme activity. At 15 DAS the treatment $W_4$ recorded the highest dehydrogenase enzyme (4.39 µg TPF $g^{-1}$ soil $day^{-1}$) which was on par with $W_2$, $W_1$ and $W_3$. At 30 DAS, $W_3$ recorded the highest dehydrogenase enzyme activity of 6.34 µg TPF $g^{-1}$ soil $day^{-1}$ which was significantly superior to other treatments and at 45 DAS, $W_1$ recorded the highest dehydrogenase activity (4.52 µg TPF $g^{-1}$ soil $day^{-1}$) which was statistically on par with $W_5$ and $W_6$. Weedy check ($W_8$) recorded the lowest dehydrogenase enzyme activity of 2.81, 3.32 and 3.67 µg TPF $g^{-1}$ soil $day^{-1}$, respectively at 15, 30 and 45 DAS.

Interaction effect was significant only at 30 DAS. At 30 DAS, the treatment combination $s_1w_3$ recorded the highest dehydrogenase activity which was on par with $s_1w_2$ and $s_2w_3$.

**4.10.2 Urease Enzyme Activity (Table 34 and 34a)**

Seed bed preparation had no significant effect on urease enzyme activity at 15, 30 and 45 DAS.

Perusal of data on weed management practices at 15 DAS indicated that $W_6$ recorded the highest urease enzyme activity (440.53 µg urea hydrolysed $g^{-1}$ soil $4h^{-1}$) which was significantly superior to other treatments. However, at 30 DAS, $W_5$ recorded the highest urease enzyme activity (482.10 µg urea hydrolysed $g^{-1}$ soil $4h^{-1}$) which was on par with $W_6$ and $W_3$. At 45 DAS, $W_7$ registered the highest urease enzyme activity (574.93 µg urea hydrolysed $g^{-1}$ soil $4h^{-1}$) which was statistically comparable with $W_6$, $W_4$ and $W_3$.

Interaction effect was significant only at 30 DAS and the treatment combination, $s_2w_5$ recorded the highest urease enzyme activity which was statistically at par with $s_2w_6$, $s_1w_6$, $s_2w_2$, $s_2w_3$ and $s_1w_7$.

4.11. ECONOMIC ANALYSIS

**4.11.1 Net Income (Table 35 and 35a)**

Stale seed bed was found more remunerative, since it recorded a net income of ₹37,838.6 $ha^{-1}$ compared to normal seed bed (₹21,821.7 $ha^{-1}$).

Among the weed management practices, $W_3$ recorded the highest net income of ₹63, 121.0 $ha^{-1}$ followed by $W_2$ and the lowest net income was recorded in $W_4$ (₹ 18, 475 $ha^{-1}$).

Among the treatment combination $s_1w_3$ recorded the highest net income of ₹ 64,775 $ha^{-1}$ which was followed by $s_2w_3$ (₹ 61,467 $ha^{-1}$).

**4.11.2 B:C Ratio (Table 35 and 35a)**

Stale seed bed recorded the highest B:C ratio of 1.43 as against normal seed bed which recorded a B:C ratio of 1.32.

Among the weed management practices, $W_3$ recorded the highest B:C ratio (1.71) and the lowest by $W_4$ (1.22).

Among the treatment combination $s_1w_3$ recorded the highest B:C ratio of 1.72 and the lowest in $s_2w_4$ (1.14).

Table 33. Effect of seed bed preparation and weed management practices on dehydrogenase enzyme activity

| Treatments | Dehydrogenase enzyme activity (μg triphenyl formazan (TPF) $g^{-1}$ soil $day^{-1}$) | | |
|---|---|---|---|
| | 15 DAS | 30 DAS | 45 DAS |
| Seed bed preparation (S) | | | |
| $S_1$ | 3.82 | 4.53 | 4.19 |
| $S_2$ | 3.55 | 3.79 | 3.79 |
| SE m (±) | 0.06 | 0.09 | 0.08 |
| CD (0.05) | 0.18 | 0.27 | 0.22 |
| Weed management practices (W) | | | |
| $W_1$ | 4.33 | 4.06 | 4.52 |
| $W_2$ | 4.34 | 5.03 | 3.93 |
| $W_3$ | 4.27 | 6.34 | 3.87 |
| $W_4$ | 4.39 | 3.54 | 3.80 |
| $W_5$ | 3.03 | 3.56 | 4.19 |
| $W_6$ | 3.00 | 3.60 | 4.18 |
| $W_7$ | 3.31 | 3.87 | 3.76 |
| $W_8$ | 2.81 | 3.32 | 3.67 |
| SE m (±) | 0.12 | 0.19 | 0.15 |
| CD (0.05) | 0.35 | 0.55 | 0.44 |

Table 33a. Interaction effect of seed bed preparation and weed management practices on dehydrogenase enzyme activity

| Treatments | Dehydrogenase enzyme activity (µg triphenyl formazan (TPF) $g^{-1}$ soil $day^{-1}$) | | |
|---|---|---|---|
| | 15 DAS | 30 DAS | 45 DAS |
| $s_1w_1$ | 4.44 | 5.01 | 4.62 |
| $s_1w_2$ | 4.81 | 6.59 | 3.97 |
| $s_1w_3$ | 4.50 | 6.64 | 3.86 |
| $s_1w_4$ | 4.47 | 3.38 | 4.19 |
| $s_1w_5$ | 3.29 | 3.32 | 4.52 |
| $s_1w_6$ | 3.11 | 3.71 | 4.65 |
| $s_1w_7$ | 3.57 | 3.87 | 3.92 |
| $s_1w_8$ | 2.88 | 3.54 | 3.79 |
| $s_2w_1$ | 4.21 | 3.11 | 4.43 |
| $s_2w_2$ | 3.87 | 3.46 | 3.89 |
| $s_2w_3$ | 4.04 | 6.03 | 3.88 |
| $s_2w_4$ | 4.31 | 3.69 | 3.41 |
| $s_2w_5$ | 2.77 | 369 | 3.86 |
| $s_2w_6$ | 2.88 | 3.50 | 3.71 |
| $s_2w_7$ | 3.05 | 3.86 | 3.60 |
| $s_2w_8$ | 2.73 | 3.10 | 3.54 |
| SE m (±) | 0.17 | 0.27 | 0.21 |
| CD (0.05) | NS | 0.78 | NS |

NS: non-significant

Table 34. Effect of seed bed preparation and weed management practice on urease enzyme activity

| Treatments | Urease enzyme activity (µg urea hydrolyzed $g^{-1}$soil $4h^{-1}$) | | |
|---|---|---|---|
| | 15 DAS | 30 DAS | 45 DAS |
| Seed bed preparation (S) | | | |
| $S_1$ | 377.59 | 411.57 | 500.93 |
| $S_2$ | 382.12 | 435.53 | 509.01 |
| SE m (±) | 6.12 | 8.66 | 9.12 |
| CD (0.05) | NS | NS | NS |
| Weed management practices (W) | | | |
| $W_1$ | 367.47 | 416.26 | 467.52 |
| $W_2$ | 372.45 | 424.33 | 512.75 |
| $W_3$ | 364.97 | 461.73 | 522.63 |
| $W_4$ | 379.78 | 375.67 | 528.87 |
| $W_5$ | 402.98 | 482.10 | 466.80 |
| $W_6$ | 440.53 | 477.40 | 531.47 |
| $W_7$ | 346.63 | 419.48 | 574.93 |
| $W_8$ | 364.02 | 331.40 | 434.80 |
| SE m (±) | 12.25 | 17.33 | 18.24 |
| CD (0.05) | 35.54 | 50.28 | 52.94 |

NS: non-significant

Table 34a. Interaction effect of seed bed preparation and weed management practices on urease enzyme activity

| Treatments | Urease enzyme activity ($\mu$g urea hydrolyzed g$^{-1}$soil 4h$^{-1}$) | | |
|---|---|---|---|
| | 15 DAS | 30 DAS | 45 DAS |
| $s_1w_1$ | 355.20 | 392.10 | 484.33 |
| $s_1w_2$ | 360.10 | 371.69 | 482.33 |
| $s_1w_3$ | 359.93 | 447.27 | 521.17 |
| $s_1w_4$ | 387.23 | 359.23 | 553.13 |
| $s_1w_5$ | 386.57 | 444.80 | 416.80 |
| $s_1w_6$ | 428.93 | 476.67 | 555.47 |
| $s_1w_7$ | 362.77 | 457.60 | 558.70 |
| $s_1w_8$ | 380.00 | 346.17 | 435.63 |
| $s_2w_1$ | 379.73 | 446.43 | 450.70 |
| $s_2w_2$ | 384.80 | 476.20 | 543.27 |
| $s_2w_3$ | 370.00 | 476.20 | 524.10 |
| $s_2w_4$ | 372.33 | 392.10 | 504.60 |
| $s_2w_5$ | 419.13 | 519.40 | 516.80 |
| $s_2w_6$ | 452.13 | 479.13 | 507.47 |
| $s_2w_7$ | 330.50 | 384.37 | 591.17 |
| $s_2w_8$ | 348.03 | 316.63 | 433.97 |
| SE m (±) | 17.32 | 24.50 | 25.80 |
| CD (0.05) | NS | 71.11 | NS |

NS: non-significant

Table 35. Effect of seed bed preparation and weed management practices on net income and B:C ratio

| Treatments | Net income (₹ $ha^{-1}$) | B:C ratio |
|---|---|---|
| Seed bed preparation (S) | | |
| $S_1$ | 37838.6 | 1.43 |
| $S_2$ | 21821.7 | 1.32 |
| SE m (±) | - | - |
| CD (0.05) | - | - |
| Weed management practices (W) | | |
| $W_1$ | 54797.0 | 1.64 |
| $W_2$ | 58857.0 | 1.67 |
| $W_3$ | 63121.0 | 1.71 |
| $W_4$ | 18475.0 | 1.22 |
| $W_5$ | 31245.5 | 1.36 |
| $W_6$ | 25385.5 | 1.29 |
| $W_7$ | 27398.0 | 1.29 |
| $W_8$ | -18816.0 | 0.77 |
| SE m (±) | - | - |
| CD (0.05) | - | - |

Table 35a. Interaction effect of seed bed preparation and weed management practices on net income and B: C ratio

| Treatments | Net income (₹ $ha^{-1}$) | B:C ratio |
|---|---|---|
| $s_1w_1$ | 57937.0 | 1.67 |
| $s_1w_2$ | 60577.0 | 1.68 |
| $s_1w_3$ | 64775.0 | 1.72 |
| $s_1w_4$ | 25025.0 | 1.30 |
| $s_1w_5$ | 33218.5 | 1.38 |
| $s_1w_6$ | 31268.5 | 1.36 |
| $s_1w_7$ | 34291.0 | 1.36 |
| $s_1w_8$ | -4383.0 | 0.95 |
| $s_2w_1$ | 51657.0 | 1.61 |
| $s_2w_2$ | 57137.0 | 1.66 |
| $s_2w_3$ | 61467.0 | 1.70 |
| $s_2w_4$ | 11925.0 | 1.14 |
| $s_2w_5$ | 29272.5 | 1.34 |
| $s_2w_6$ | 19502.5 | 1.23 |
| $s_2w_7$ | 20505.0 | 1.22 |
| $s_2w_8$ | -33249.0 | 0.58 |
| SE m (±) | - | - |
| CD (0.05) | - | - |

# DISCUSSION

# 5. DISCUSSION

The results of the field experiment "Integrated weed management in bush type vegetable cowpea (*Vigna unguiculata* subsp. *unguiculata* (L.) Verdcourt) laid out at Coconut Research Station, Balaramapuram are discussed in this chapter.

## 5.1 HERBICIDE APPLICATION AND PHYTOTOXICITY SYMPTOMS IN CROP

To assess the phytotoxicity if any on the application of herbicides on crop, phytotoxicity rating scale of 0-10 was adopted for the visual scoring of phytotoxicity symptoms. Observations clearly revealed that the herbicides diclosulam at 12.5 g $ha^{-1}$, quizalofop-p-ethyl @ 50 g $ha^{-1}$ and imazethapyr 50 @ g $ha^{-1}$ did not produce any visible phytotoxicity symptoms and all the three herbicides recorded a rating of one. The result is in conformity with the findings of Tomar (2011), Deepa *et al*. (2017) and Kumar *et al*. (2016) who revealed that quizalofop-p-ethyl even at a dose of 1500 ml $ha^{-1}$, diclosulam @17.5 g $ha^{-1}$ and imazethapyr @100 g $ha^{-1}$ did not produce any phytotoxic symptom in black gram and green gram.

## 5.2 EFFECT OF WEED MANGEMENT TREATMENTS ON GROWTH PARAMETERS

Stale seed bed had significant effect on growth parameters, *viz*., plant height at 20 and 40 DAS, number of leaves at 20 and 60 DAS, number of branches at 40 and 60 DAS and plant dry weight at 20, 40 and 60 DAS. Though plant height was not significant at 60 DAS, plant height was increased with the progress of crop growth in all the treatments. However, number of branches increased up to 40 DAS, thereafter remained constant. Compared to normal seed bed, SSB recorded higher values for all the growth parameters. This was owing to the fact that initial flushes of weeds were destroyed in SSB before sowing of seeds, this would reduce the CWC in the early stages of the crop development. Early weed free situation allowed the crop to utilize the above and below ground resources and resulted in higher number of leaves, branches and DMP. Corroboratory results were also reported by Ravikiran (2018) in upland rice and Senthilkumar *et al.* (2019) in groundnut.

Compared to weedy check, weed management treatments recorded significantly higher plant height at 20 and 40 DAS, leaves per plant and DMP at all the three stages and branches per plant at 20 DAS. This was due to lesser crop weed competition (CWC) during the critical stages of the crop growth. Reduced CWC improved the root growth and enhanced the nutrient availability and moisture which in turn contributed to better expression of growth attributes. The result is in accordance with the observations made by Bangi *et al.* (2014), Patel *et al*. (2017) and Chaudhari *et al*. (2019) who reported that reduced CWC in the critical stages of crop growth significantly improved the growth attributes in brinjal, okra and tomato. Weed control resulted in 4.27 to 28.82, 10.57 to 19.25 and 5.28 to 18.41 percentage increase in DMP at 20, 40 and 60 DAS, respectively. Higher DMP recorded in weed management treatments was due to increase in plant height, higher number of leaves and branches (Table 3, 4 and 5) which in turn increased the assimilatory area, photosynthesis and dry matter accumulation. Higher DMP in weed control treatments can also be explained in terms of higher LAI, CGR and RGR. Weedy check recorded significantly lower values for the growth attributes. This was due to season long CWC which might have reduced the availability of nutrients, water, sunlight and space. All these factors affected the photosynthesis and translocation of assimilates from source to sink and resulted in lower DMP. Sah *et al*. (2018) reported that weed interferences during the crop growth adversely affected the growth attributes.

Among the growth parameters, interaction effect was significant for plant height only at 20 DAS and leaves per plant at 60 DAS. The treatments with SSB followed by weed management treatments recorded higher values for the growth parameters compared to normal seed bed followed by weed management practices. The reason was due to the favourable environment brought out by reduced crop weed interference which might have enhanced the availability of nutrients, space, water and light that resulted in the better expression of growth attributes.

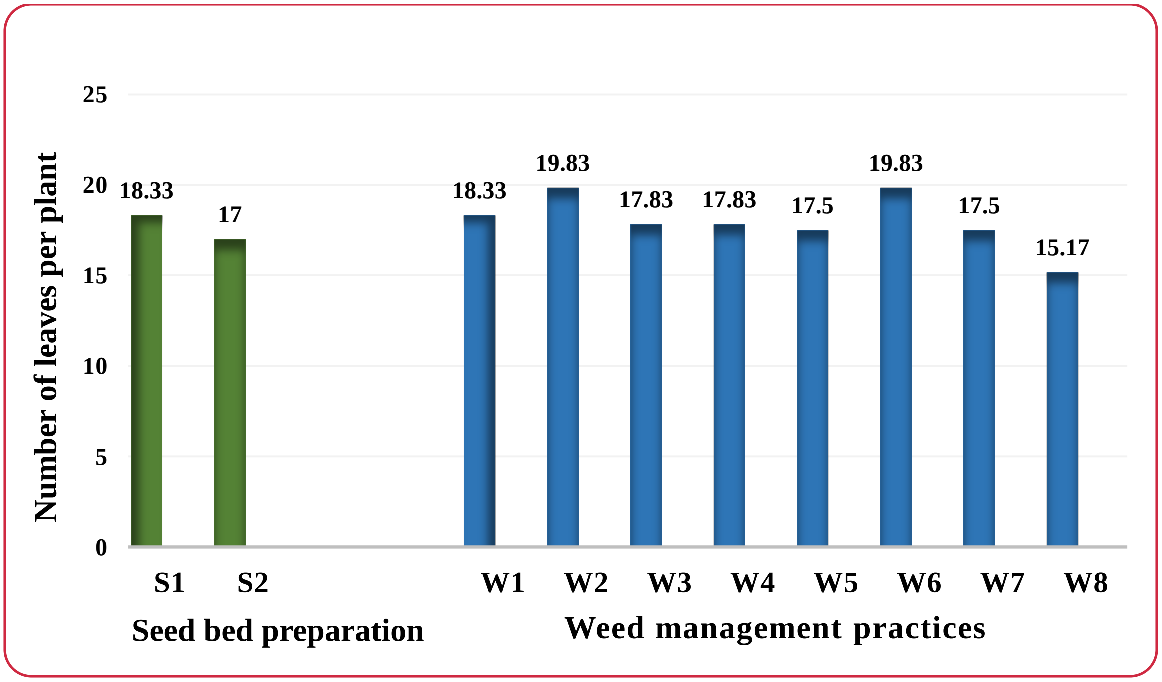


Fig 3. Effect of seed bed preparation and weed management practices on number of leaves per plant at 60 DAS

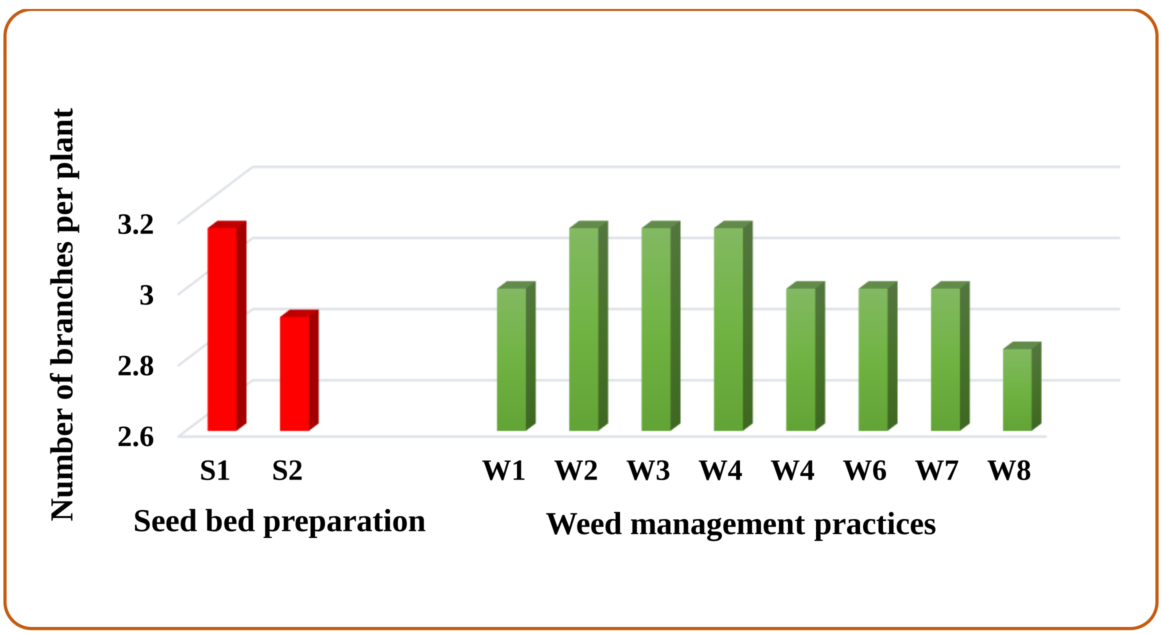


Fig 4. Effect of seed bed preparation and weed management practices on number of branches per plant at 60 DAS

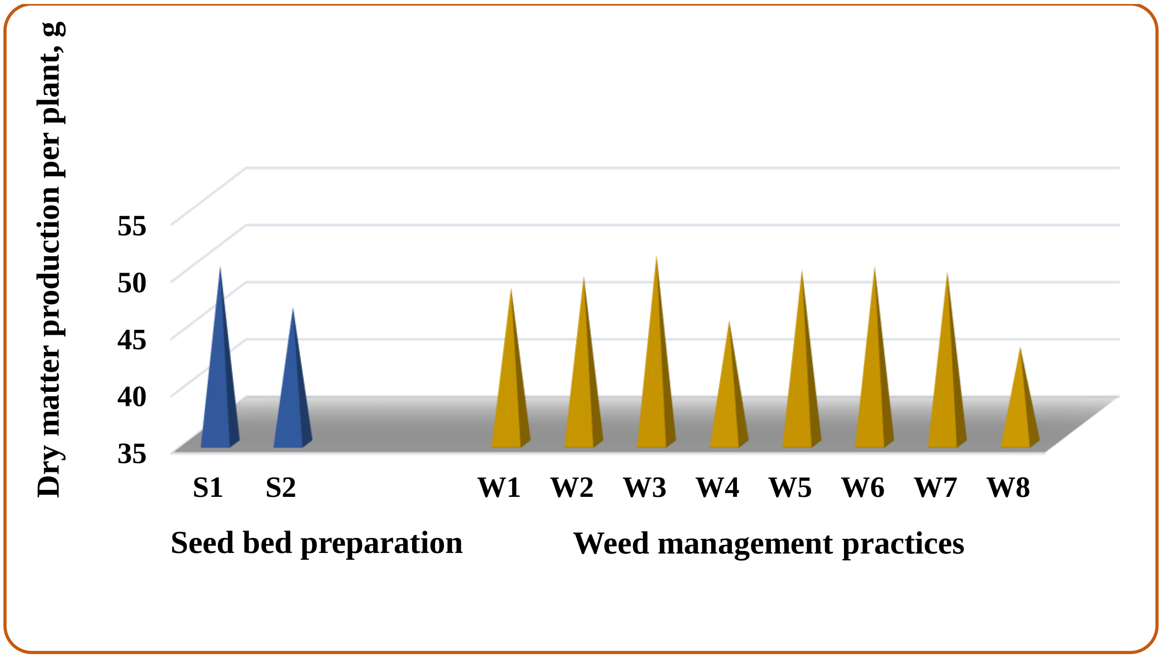


Fig 5. Effect of seed bed preparation and weed management practices on dry matter production per plant at 60 DAS.

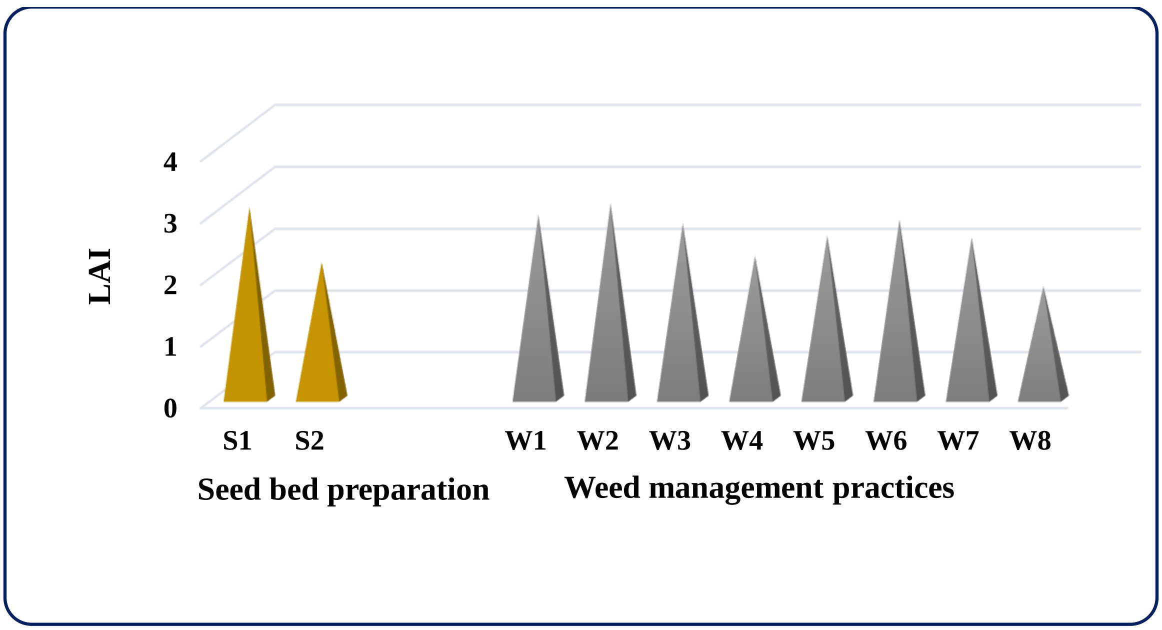


Fig 6. Effect of seed bed preparation and weed management practices on LAI at 60DAS

## 5.3 EFFECT OF WEED MANAGEMENT TREATMENTS ON PHYSIOLOGICAL PARAMETERS

Leaf area index was significantly influenced by seed bed preparation and weed management practices at 20, 40 and 60 DAS. Competitive advantage over the weeds due to pre sowing management of weeds resulted in better crop growth in SSB. Higher root growth (Table 12 and 13) observed in SSB also enabled the crop plant to tap sufficient amount of nutrients from the soil for effective photosynthesis and enabled the crop to produce higher number of leaves with larger leaf area, branches per plant and DMP (Table 5, 6 and 7). Higher number of effective nodules and nodule fresh weight observed in SSB might have also increased the N fixation and N assimilation by plant and enhanced the crop growth. The result is in consonance with findings of Veermani *et al*. (2006) who observed that SSB with paraquat application recorded higher LAI. Normal seed bed recorded lesser value for LAI at all the three stages of observation, where the plants might have experienced severe competition for growth factors particularly, nutrients, space and moisture due to the presence of larger number of weeds (Fig.17) with higher DMP (Fig.5).

Crop growth rate was also influenced by seed bed preparation, however RGR was not significantly influenced. Significantly higher CGR observed in SSB at both the time intervals (20-40 DAS and 40-60 DAS) might be due to the increase in LAI and DMP observed (Fig. 5 and Fig. 6). Increase in leaf area intercepts more solar radiation and consequently increased the DMP at various growth stages (Amanullah *et al*., 2008). Veeramani *et al*. (2006) reported that SSB recorded higher CGR in cotton due to higher LAI and DMP resulting from the better availability and uptake of nutrients as a result of reduced CWC. Similar to that of RGR, chlorophyll a, b and total chlorophyll content at 40 DAS and chlorophyll a at 60 DAS was not significantly influenced by seed bed manipulation. Significantly higher total chlorophyll content observed at 60 DAS might be due to reduced CWC which in turn enhanced the assimilatory area with higher chlorophyll content as evident from the data on number of leaves per plant (Table 4).

Weed management practices also significantly influenced the physiological parameters of bush type vegetable cowpea. In general, weed management treatments recorded significantly higher LAI compared to weedy check. This was due to severe CWC which adversely affected the growth of crop. Channappagoudar *et al*. (2013) reported that weedy check recorded the lowest LAI in brinjal due to severe CWC. The treatments with dried banana leaf mulch recorded higher LAI compared to other weed management treatments. This was due to the presence of higher number of leaves with large leaf area in these treatments (Table 7). El-Khader *et al*. (2010) who observed that organic mulches enhanced the plant growth which resulted in large canopy coverage. Favourable soil microclimate created by mulching might have helped in better growth of roots (Table 12 and 13) which enabled the plant to draw nutrients from deeper layers. Better availability of nutrients due to the gradual decomposition of dried banana leaf as well as tapping of nutrients from deeper layers and its translocation contributed to better vegetative growth and finally resulted in higher LAI. Carmichael *et al*. (2012) reported that mulching with organic materials enhanced the LAI in radish and control the weeds to a great extent.

Crop growth rate and RGR were significantly influenced by weed management practices. Crop growth rate gave an indication of net rate of photosynthesis, respiration and solar radiation interception by the foliage. Crop growth rate increased with the progress of crop growth, whereas RGR declined with the crop growth due to less dry matter accumulation. At both stages of observation (20 to 40 DAS .and 40 to 60 DAS), weedy check recorded significantly lower CGR and RGR compared to other weed management treatments. This was due to significantly lower DMP recorded at 20, 40 and 60 DAS in weedy check. Lower DMP recorded in weedy check (Fig. 5) might be due to severe CWC as evident from the data on total weed density and weed dry weight and reduced root growth (Table 12 and 13) which might have affected the uptake and translocation of nutrients to the growing plant parts and finally hinder the growth of the crop plant. Yadav *et al*. (2019) reported that CGR and RGR was found to be the lowest in weedy check in green gram.

Chlorophyll content was also significantly influenced by weed management practices. Weedy check recorded the lowest total chlorophyll content at 40 and 60 DAS. This was as a result of severe CWC. The result is in line with the observation of Qiu *et al*. (2007) who observed that environmental factors have significant effect on chlorophyll content. Procopio *et al*. (2004) revealed that CWC adversely affect the physiological parameters especially the chlorophyll content through its effect on the availability of $CO_2$ to leaf mesophyll and leaf temperature. Weed management treatments recorded higher chlorophyll content was owing to the fact that lesser CWC favoured the root growth which might have enabled the crop to absorb adequate amount of nutrients from the soil for the synthesis of the chlorophyll and enhanced photosynthesis. Hakim *et al*. (2013) reported that maximum chlorophyll content was observed in weed free treatment and minimum in weedy check in rice. Olorunmaiye (2010) also reported that weed competition significantly lowered the chlorophyll content in cowpea. Interaction effect was also significant. Compared to control ($s_2w_8$), all the treatment combinations recorded higher chlorophyll content might be due to less weed interference which might have provided a favourable environment for the complete development of the canopy with higher LAI.

## 5.4 EFFECT OF WEED MANAGEMENT TREATMENTS ON NODULE PARAMETERS

Seed bed preparation had significant effect on total nodules, effective nodules and nodule fresh weight per plant. Due to the manipulation of seed bed 26.32 per cent increase in total nodules per plant, 49.05 per cent increase in effective nodules per plant and 28.95 per cent increase in nodule fresh weight per plant has been observed in SSB. Reduction in the density and dry weight of weeds in SSB minimized the competition for nutrients which would ultimately increase the availability and uptake of nutrients. Better availability and uptake of nutrients favoured the crop growth which will enhance the photosynthesis and translocation of photosynthates to the root nodules resulted in the development of a greater number of root nodules with more weight. Raman and Krishnamoorthy (2005) and Chatta *et al.* (2007) observed that poor plant growth adversely affected the nodule formation.

Tehria *et al*. (2015) reported that in pea, nodule count was found to be the highest in SSB compared to herbicide treatment.

In general, compared to weedy check, all the weed management treatments recorded higher number of nodules, effective nodules and nodule fresh weight per plant. The result is in accordance with the observations of Kumar *et al*. (2017) who observed that higher competition for growth factors in weedy check resulted in poor crop growth which caused lesser number of nodules and nodule weight in mung bean. Though the weed management treatments recorded higher number of root nodules variation in the number and nodule weight was observed among the treatments due to the specific soil condition prevailed in each treatment and also due to the variation in organic matter content. Walley *et al*. (2006) reported that effect of herbicide treatments on nodulation depends on the specific soil condition, moisture content, soil organic matter and weather condition.

The interaction effect was also found significant and the treatment combination $s_1w_6$ recorded higher number of total nodules and effective nodules compared to other treatments. This was owing to the fact that, beneficial effect of SSB coupled with pre emergence application of diclosulam resulted in the effective control of weeds as evident from the data on total weed dry weight at 15 DAS enabled the crop to grow vigorously resulting in the effective transport of photosynthates from leaves to nodules. Sharma *et al*. (2017) observed that pre-emergence pendimethalin followed by hand weeding at 30 DAS recorded higher number of nodules and dry weight in soybean. Though higher number of nodules was recorded in $s_1w_6$, the nodule fresh weight was more in $s_1w_3$ which might be due to the formation of bigger size nodules.

## 5.5 EFFECT OF WEED MANAGEMENT TREATMENTS ON ROOT PARAMETERS

Stale seed bed significantly influenced the root volume at 20 DAS and root fresh weight at 20 DAS and 60 DAS. Though the root volume was non-significant at 40 and 60 DAS and root fresh weight at 40 DAS, SSB recorded higher values of root volume and root fresh weight. This might be due to the fact that SSB provided early weed free condition which reduced the competition for major inputs *viz*., nutrients, water and space that enables the plant to grow vigorously and have better root growth by increasing the density as well as foraging area of the roots. Higher density of weeds (Fig.17) which caused severe competition for nutrients, water and space which ultimately resulted in reduced root growth in normal seed bed. Chadhar *et al*. (2014) reported that competition pressure due to weed infestation resulted in reduced root growth.

Weed management practices also influenced the root parameters. In general, compared to weedy check, weed management treatments recorded higher root fresh weight and root volume. An increase in fresh root weight of 2.7 to 27.8, 12.8 to 24.5 and 5.0 to 41.2 percent, respectively was observed due to weed control at 20, 40 and 60 DAS, respectively. This is because, effective control of weeds reduces the CWC and provided a soil environment favourable for better root growth. The result is in conformity with the observations of Fayed *et al*. (2018) who reported that better control of weeds using herbicides resulted in better root length and root density in wheat. It was also observed that treatments with dried banana leaf mulch recorded higher fresh root weight and root volume compared to other weed management treatments. Lamont (2005) observed that mulches reduces the weed density, evaporation of moisture from the soil surface, leaching of nutrients and reduces soil compaction. All these factors favoured the better availability and uptake of nutrients and resulted in better root growth. Dukare *et al*. (2017) reported that organic mulches enhanced the root fresh weight to a tune of 62.31 per cent as compared to no mulch in black gram.

The interaction effect was significant only at 20 and 60 DAS. The treatment combination, $s_1w_3$ recorded higher root fresh weight and root volume compared to other treatments. Initial flushes of weeds in the seed bed was destroyed before sowing the seeds in SSB, this would reduce the weed density and competition and also the later emerged grassy weeds were effectively controlled by the application of quizalofop-p-ethyl at 25 DAS. Mulching with dried banana leaf also suppressed the weeds and favourably influenced the soil microclimate, this also contributed to better root growth in $s_1w_3$. Ashrafuzzaman *et al*. (2014) reported that mulching increased the root volume and root fresh and dry weight of chilly.

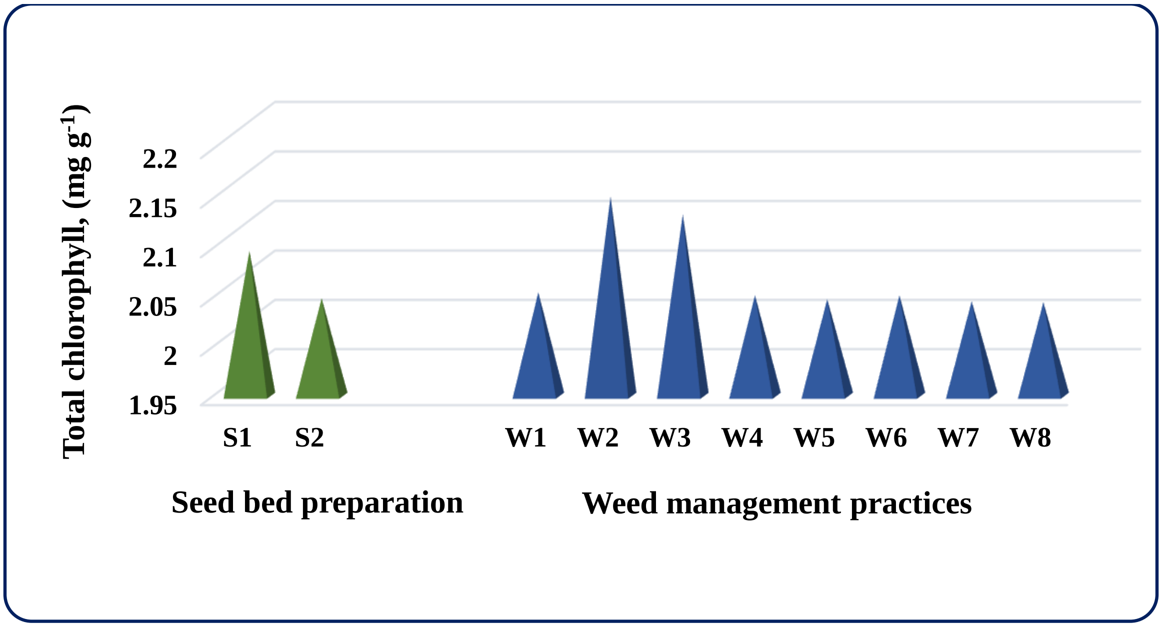


Fig 7. Effect of seed bed preparation and weed management practices on total chlorophyll content at 60 DAS

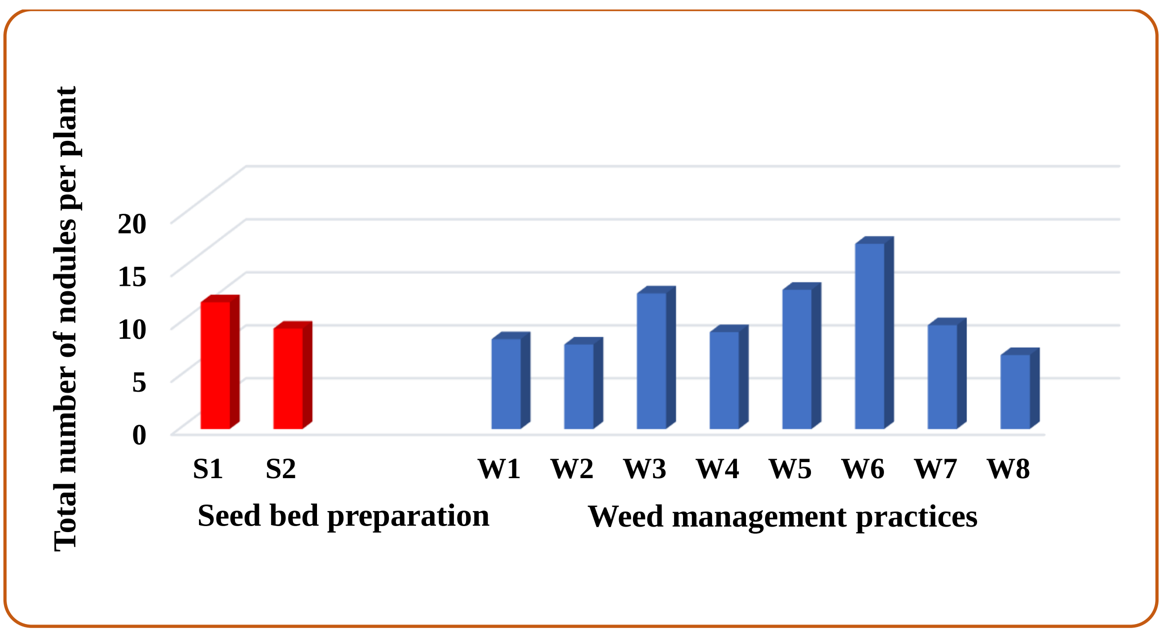


Fig 8. Effect of seed bed preparation and weed management practices on total number of nodules at flowering stage

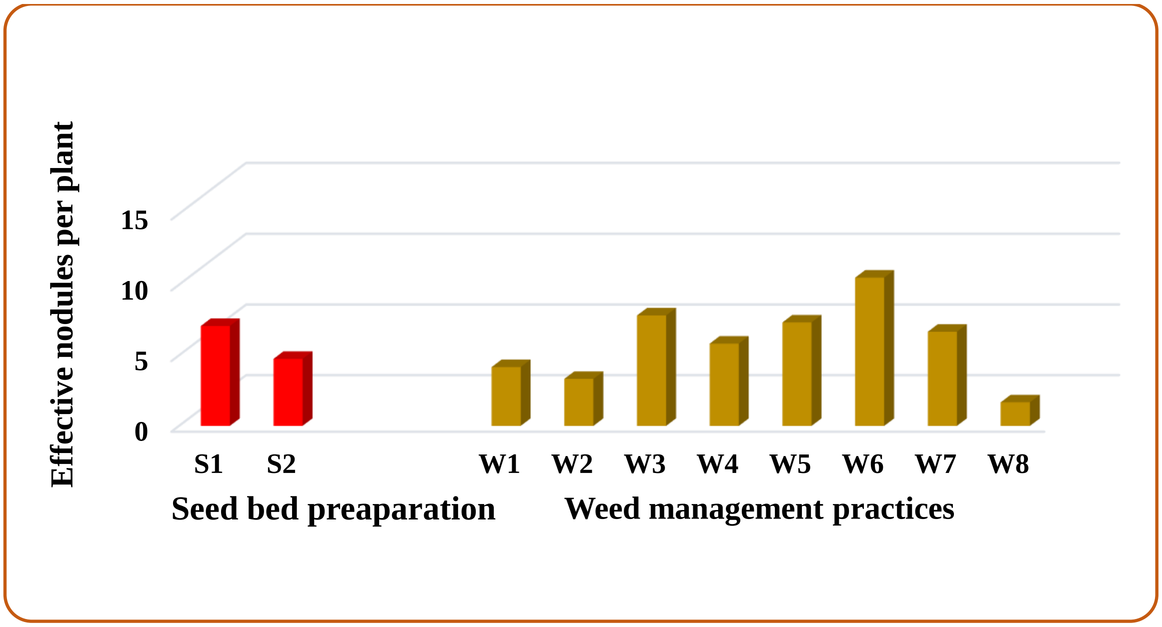


Fig 9. Effect of seed bed preparation and weed management practices on effective nodules at flowering stage

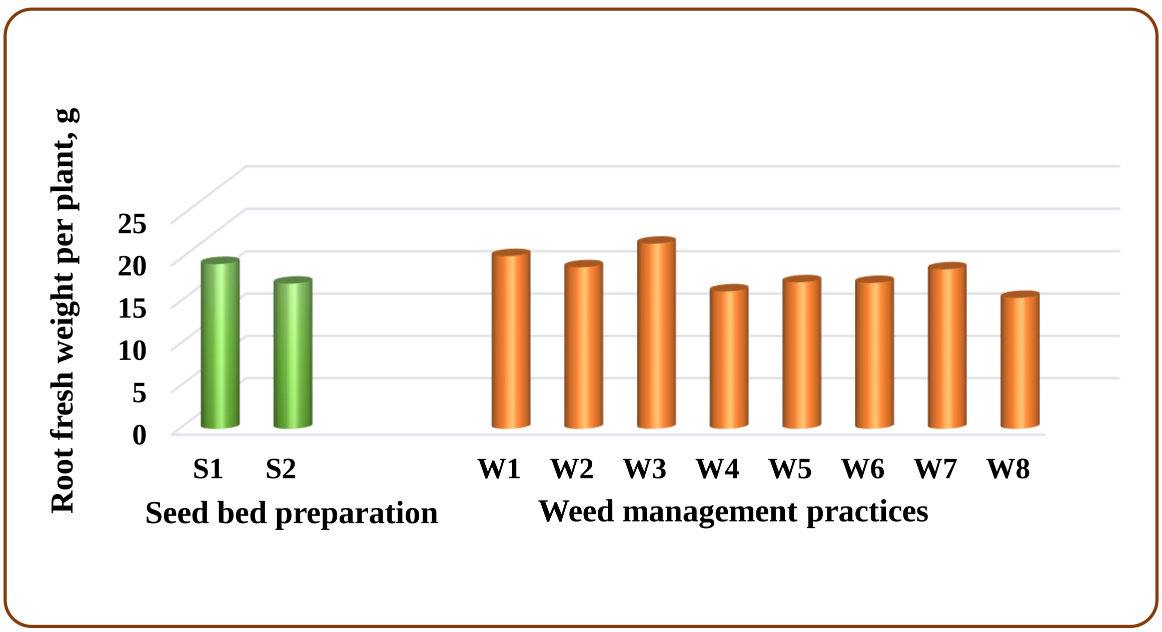


Fig 10. Effect of seed bed preparation and weed management practices on root fresh weight per plant at 60 DAS

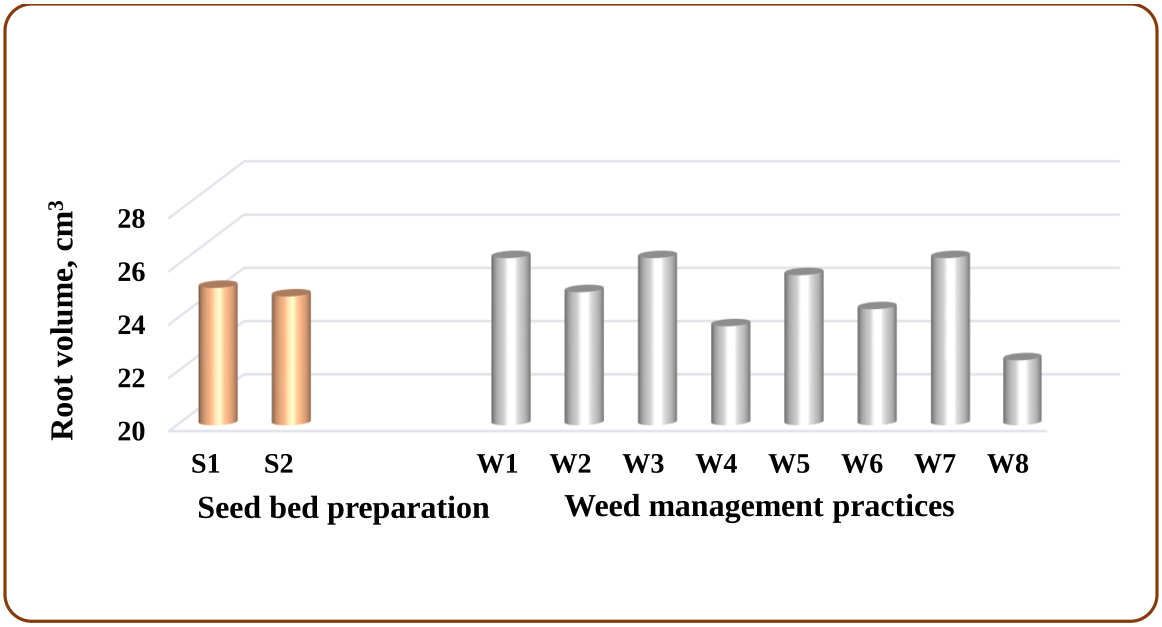


Fig 11. Effect of seed bed preparation and weed management practices on root volume at 60 DAS

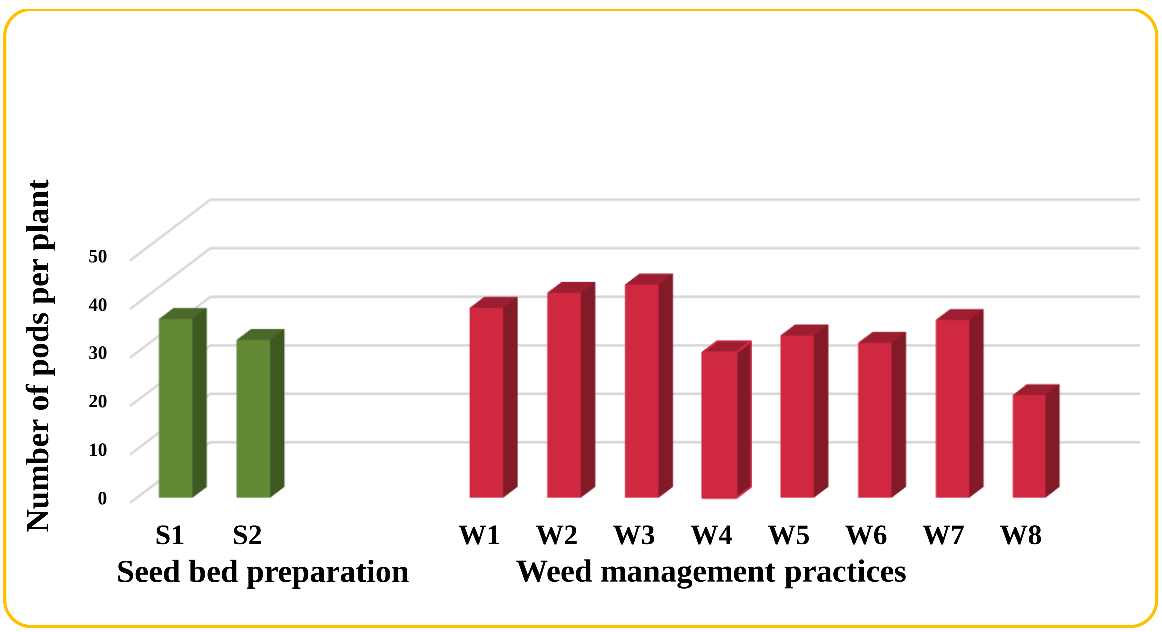


Fig 12. Effect of seed bed preparation and weed management practices on number of pods per plant

## 5.6 EFFECT OF WEED MANAGEMENT TREATMENTS ON YIELD ATTRIBUTES

Seed bed preparation significantly influenced the yield attributes of bush type vegetable cowpea. Stale seed bed recorded lesser number of days to achieve 50 per cent flowering, higher number of pods per plant, pod length and pod weight. This was due to the better availability and uptake of nutrients (Fig. 20, 21 and 22) and increased photosynthesis and translocation of assimilates from source to sink. Management of weeds before the sowing of seeds reduced the total density of weeds (Fig. 12) and dry weight (Fig. 18) with higher WCE (Fig. 19) facilitated the crop to have lesser crop weed competition for the resources which led to better expression of yield attributes. Better root growth (Fig. 10 and 11) and nodulation (Fig. 8 and 9) helped the plant to draw more amount of nutrients from deeper layers and fix higher amount of atmospheric N contributed to higher DMP which also paved the way for the better expression of yield attributes in SSB. Singh and Singh (2012) reported the favourable influence of SSB on the production of yield attributes in irrigated direct seeded rice. Arora and Tomar (2012) revealed that SSB recorded higher number of pods per plant and 100 kernel weight in groundnut compared to soil solarization and deep ploughing.

Weed management practices significantly influenced the yield attributes *viz*., number of pods per plant, pod girth and pod length. However, days to 50 per cent flowering was not significantly influenced. Weedy check recorded significantly lower values for the yield attributes. This was attributed to the fact that severe weed competition significantly reduced the uptake of nutrients (Fig. 20, 21 and 22) which resulted in lesser DMP. The lowest DMP recorded in weedy check was due to the production of lesser number of branches and also due to reduced photosynthesis as evident from the data on green leaves per plant (Table 4), LAI (Table 7) and total chlorophyll content (Fig. 7). Mirshekari (2008) reported that weed competition significantly reduced the number of pods per plant. Sharma *et al*. (2004) reported that severe weed infestation reduced the number of seeds per pod in *Phaseolus vulgaris* L. Similarly, Kumawat *et al*. (2017) opined that weedy check recorded significantly lower 1000 weight of seed in cluster bean due to CWC. It was also revealed that dried banana leaf was very effective in suppressing the weeds to a great extent. Mani *et al*. (2016) reported that rice straw mulch @ 6 t ha$^{-1}$ recorded higher number of tillers and significantly higher test weight compared to no mulch in wheat.

Among the weed management treatments, $W_3$ recorded higher number of pods per plant, pod girth and pod weight. This might be due to the favourable influence of dried banana leaf in suppressing the weeds in the early stages of crop growth and also the indirect beneficial effect of dried banana leaf as organic mulch material in moisture conservation, soil temperature regulation and supply of nutrients by favouring microbial decomposition. The later emerged weeds in this treatment especially grassy weeds were effectively controlled by the application of quizalofop-p-ethyl at 25 DAS. Better control of weeds reduced the CWC and create a congenial environment for the development of roots and higher number of nodules per plant. All these factors contribute to better availability of nutrients and resulted in greater uptake of nutrients, higher dry matter production, synthesis of photosynthates and translocation of photosynthates from source to sink which finally led to the production of higher number of pods per plant and pods with higher girth and weight. Mundra and Maliwal (2012) reported that post emergence quizalofop-p-ethyl @ 50 g ha$^{-1}$ at 4-6 leaf stage of weeds significantly reduced the density and dry weight of narrow leaved weeds and recorded higher number of pods and seeds per pod in black gram. Compared to $W_1$, the treatment $W_2$ recorded significantly higher number of pods per plant. This was due to the beneficial effect of dried banana leaf in suppressing the weeds in the initial stages followed by the effective control of BLW (Table 18, 19 and 20) and thus reducing the total weed density and dry weight by the post emergence imazethapyr. The treatment $W_4$ recorded lower number of pods per plant and pods with lower length, girth and weight compared to $W_5$ and $W_6$. This was ascribed to the fact that in treatment $W_4$, the herbicide was applied only at 15 DAS, hence the weeds emerged along with the germinating crop and exerted competition for the growth factors. Imazethapyr was found more effective against BLW, hence the grassy weeds which were not controlled compete with the crop for the resources. The result is in conformity with the observation of Thakare *et al*. (2015) who observed that post emergence imazethapyr @100 g ha$^{-1}$ alone was found

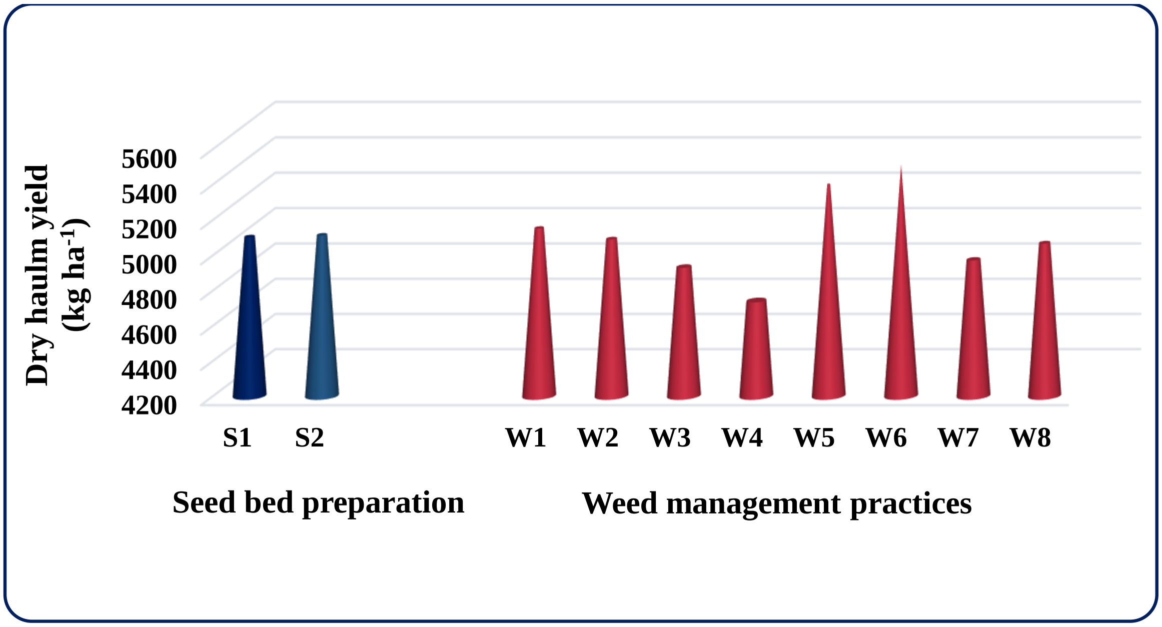


Fig 13. Effect of seed bed preparation and weed management practices on dry haulm yield

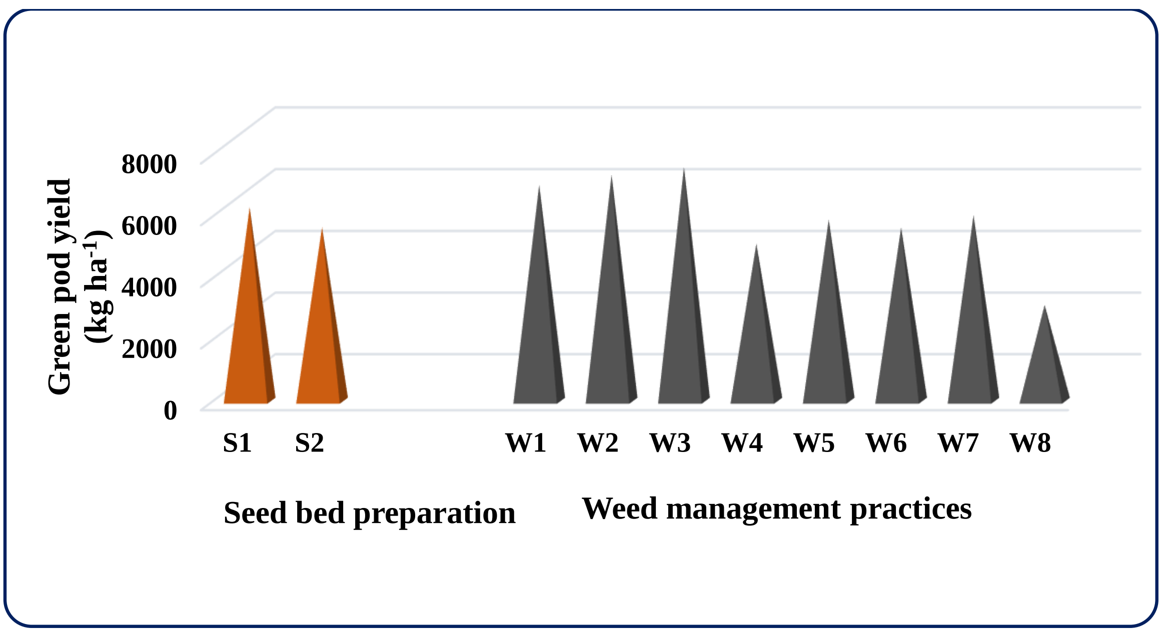


Fig 14. Effect of seed bed preparation and weed management practices on green pod yield

less effective in controlling weeds and resulted in lesser number of pods per plant and seeds per pod in black gram.

The interaction effect was found significant for number of pods per plant and pod weight. Among the treatment combination, the highest number of pods per plant and higher pod weight was observed in $s_1w_3$ which was statistically on par with $s_1w_2$. The better expression of yield attributes in these treatments was due to the favourable influence of SSB in destroying the earlier flushes of weeds before the sowing of seeds and the beneficial effect of dried banana leaf mulch in controlling the weeds in the initial stages of crop growth (Table 21) and the effective control of later emerged weeds by the application of quizalofop-p-ethyl and imazethapyr @ 50 g ha$^{-1}$ (Table 21). Sindhu *et al*. (2010) reported that SSB reduced the CWC which resulted in better emergence percentage and seedling vigour and have competitive advantage over the weeds. The reduction in weed growth facilitated vigorous crop growth, enhanced photosynthesis and dry matter accumulation resulted in the better expression of yield attributes.

## 5.7 EFFECT OF WEED MANAEMENT TREATMENTS ON YIELD, HARVEST INDEX AND WEED INDEX

Seed bed preparation significantly influenced the green pod yield per plant, total green pod yield ha$^{-1}$ and harvest index. Haulm yield per plant and per hectare were not significantly influenced by seed bed manipulation. Stale seed bed recorded 11.50 per cent yield enhancement over normal seed bed. The yield increase observed in SSB over normal seed bed was due to lesser CWC (Table 21 and 25) especially in the early stages of crop growth. Control of first flushes of weeds before the sowing of cowpea enabled the crop to grow vigourously with greater number of branches and green leaves and produce more roots which resulted in increased uptake of nutrients, photosynthesis and translocation of assimilates from source to sink. Higher availability and uptake of nutrients which helped the plants to produce higher number of pods per plant with higher pod length, girth and weight (Table 14). Better expression of yield attributes was the reason for higher green pod yield in SSB. Gopinath *et al*. (2009) reported that better initial crop growth and development attained due to the absence of CWC resulted in higher green pod yield in garden pea. Kumar *et al*. (2018b) revealed that SSB with glyphosate @1.25 kg ha$^{-1}$ recorded significantly higher jute yield compared to farmers practice (normal seed bed) due to better control of first flushes of weeds. Higher harvest index registered in $S_1$ (SSB) was owing to higher pod yield and lesser haulm yield recorded in the treatment.

Weed management practices also significantly influenced the pod and haulm yield per plant and hectare and harvest index. Due to the adoption of weed management practices green pod yield of bush type vegetable cowpea was enhanced from 3313.7 to 7589.0 kg ha$^{-1}$. Weed competition caused a yield reduction of 38.99 to 58.97 per cent in bush type vegetable cowpea. The finding is in accordance with the observations made by Osipitan *et al.* (2016) who reported that 25 to 76 per cent yield loss occurred in cowpea due to weed infestation alone depending upon the variety used and environmental condition. Weedy check recorded significantly lower green pod yield among the treatments, due to the production of lesser number of pods per plant with lesser length and weight (Table 14). Season long crop competition affect the crop growth which might have reduced the green pod yield in weedy check. Similar observations were also made by Mekkonen *et al.* (2016). Among the weed management treatments, $W_4$ recorded the lowest green pod yield. This was ascribed to fact that post emergence application of imazethapyr alone was not effective in controlling the weeds as manifest from the data on total weed density and dry weight (Table 21 and 25). The result is in accordance with the observations of Kaur *et al*. (2016) who observed that post emergence imazethapyr @ 50 g ha$^{-1}$ failed to create a weed free situation up to 40 DAS due to its poor efficacy in controlling grassy weeds and sedges and resulted in lower seed yield in green gram. The results clearly revealed that mulching or pre emergence herbicide was essential to check the weeds which emerged fast and gain competitive advantage over the crop due to slow initial growth of cowpea. The treatment $w_3$ recorded the highest green pod yield and harvest index might be due to the production of higher number of pods per plant (Fig.12). Mulching with dried banana leaf followed by post emergence quizalofop-p-ethyl provided a weed free period during the critical stages of the crop which enabled the crop to grow without any competition and resulted in the production of higher number of pods per plant and led to higher pod yield. The treatments

$W_1$, $W_2$ and $W_3$ recorded higher green pod yield and harvest index compared to $W_5$ and $W_6$, might be due to the favourable influence of dried banana leaf mulch in buffering the soil temperature and moisture conservation in addition to the beneficial effect of weed suppression, thus providing an optimum condition for the utilization of available nutrients (Table 27) for growth and yield. Mani *et al*. (2016) reported that mulching with straw much @ 6 t $ha^{-1}$ reduced the density and dry weight of weeds by 50 per cent and increased the yield by 34 per cent compared to no mulch. Pre emergence diclosulam 12.5 g $ha^{-1}$ *fb* quizalofop-p-ethyl recorded on par yield with hand weeding twice. The result revealed the efficacy of pre-emergence diclosulam in the broad-spectrum control of weeds in the early stage of crop. Nainwal *et al*. (2010) reported that pre emergence diclosulam @ 18 g $ha^{-1}$ *fb* post emergence haloxyfop @ 100 g $ha^{-1}$ recorded higher yield in soybean. Though the treatments $W_6$ and $W_5$ recorded higher green pod yield than $W_4$, the harvest index was found to be lower. This was because of higher haulm yield registered in these treatments due to higher vegetative growth compared to $W_4$ (Fig.13).

The interaction between seed bed preparation and weed management practices was found significant for green pod yield, haulm yield and harvest index. The treatment combination, $s_1w_3$ recorded the highest green pod yield and harvest index and the lowest haulm yield. This was owing to the fact that low CWC provided a stress-free environment for the best utilization of resources resulted in the production of higher number of pods per plant and pods with higher length and weight (Table 14a) which contributed to higher green pod yield. Higher total chlorophyll content and LAI registered in the treatment significantly improved the photosynthesis and partitioning of assimilates from source to sink resulted in lower haulm yield in $s_1w_3$ compared to other treatments.

## 5.8 EFFECT OF WEED MANAGEMENT TREATMENTS ON PROTEIN CONTENT

Protein content of the pod was significantly influenced by seed bed manipulation. Compared to normal seed bed, SSB recorded higher protein content. This might be due to the fact that SSB reduced crop weed competition and enhanced the availability and uptake of N with high N content. Higher N content stimulated the synthesis of the amino acids. Sudha and Stalin (2015) revealed that increased buildup of amino acids enhanced the protein content of the grain. Raj (2019) also reported that increased availability and uptake of N increased the protein content of cowpea grain.

Weed management practices also significantly influenced the protein content of pod. Compared to weedy check, all the weed management treatments recorded higher protein content due to higher N content of the pod. This was owing to the fact that adoption of weed management practices significantly reduced the CWC which favoured the crop growth with higher DMP (Fig. 5). Lesser CWC also enhanced the availability and uptake of nutrients (Fig. 20, 21 and 22) and better translocation of N from leaves to green pod which led to higher N content. Higher N content trigger the synthesis of amino acids and protein synthesis in pods and enhanced the protein content of the pod. Chandolia *et al*. (2010) reported that weed management practices significantly improved the protein content of groundnut kernel due to higher N content of the kernel. Compared to other weed management treatments, treatments with dried banana leaf mulch recorded higher protein content might be due to the favourable influence of mulching on enhancing the plant growth thereby increased the uptake of nutrients and resulted in higher pod yield with higher N content. Acharya and Sharma (1994) revealed that mulching significantly enhanced the uptake of N, P and K. compared to control (no mulch). Hingonia *et al*. (2016) reported that mulching with organic material @ 6 t $ha^{-1}$ enhanced the protein content of barley.

## 5.9 EFFECT OF WEED MANAGEMENT TREATMENTS ON WEED PARAMETERS

Results on the data on absolute density and relative density of weeds revealed that both the BLW and grassy weeds were present almost in equal proportions (Table 18, 19, 20, 22, 23 and 24), however sedges population was very less. *Setaria barbata* and *Digitaria sanguinalis* were the major grassy weeds present in the field, *Spermacoce latifolia*, *Alternanthera sessilis*, *Phyllanthus niruri* and *Synedrella nodiflora* were the dominant BLW and the only sedge present was *Cyperus rotundus*. Extensive studies conducted by IIPR (2009) also revealed that in pulses, the infestation of sedges is comparatively less and the predominant one observed was *Cyperus rotundus*.

Seed bed manipulation had a significant effect on reducing the absolute density of grasses, BLW, total density and dry weight of weeds and WCE at all the three stages. However, seed bed manipulation did not have any significant effect on absolute density and relative density of sedges at all three stages of observation and relative density of grasses and BLW on 15 DAS. Non-significant effect of seed bed preparation on absolute density and relative density of sedges at all the three stages of observation might be due to comparatively less population of sedges observed in the experiment field (Table18, 19 and 20). Significantly lower absolute density and dry weight and higher WCE observed in SSB might be due to removal of germinated weeds prior to planting, resulted in the depletion of weed seed bank in the surface soil and subsequent emergence of weeds. Johnson and Mullinix (2000) also observed that SSB brought out significant reduction in weed seed bank and subsequent weed seed emergence. Several researchers (Standiner, 1980; Chauhan and Johnson, 2008; 2010, Singh and Singh, 2012) revealed that SSB was very effective in reducing the density of grasses, sedges and BLW which have low seed dormancy and present on the surface soil. Pandey *et al*. (2009), Arora and Tomar (2012) and Tehria *et al*. (2015) also reported that due to significant reduction in weed density, SSB recorded the lowest weed dry weight in direct seeded rice, groundnut and pea, respectively. Higher WCE registered in SSB might be due to significantly lower dry weight registered in this treatment (Fig. 18). Sindhu *et al*. (2010) and Ravikiran *et al*. (2019) revealed that adoption of SSB significantly enhanced the WCE over no stale (normal seed bed). Lower WI registered in SSB might be due to higher yield registered in the treatment compared to no stale seed bed (normal seed bed) (Table 16)

With regard to data on absolute density of weeds revealed that predominance of grassy weed was observed at 15 DAS, however at 30 and 45 DAS, BLW was the predominant one. The population of sedges was found very less in number. Weedy check recorded significantly higher absolute density, total density and dry weight of weeds and WI and lower WCE. The reason for higher absolute density, total density and dry weight of weeds was due to the fact that unweeding resulted in uninterrupted weed growth throughout the crop growth period which led to higher weed density and dry weight (Table

21 and 25). Better control of weeds showed reduction in weed density and dry weight of weeds which provided a favorable environment for the crops to grow vigorously and smother the weeds resulted in higher WCE in weed management treatments. Naidu *et al*. (2012) pointed out that significant reduction in weed growth due to weed management practices enhanced the photosynthesis and DMP of crop which helped to smother the weeds and increased the WCE. Among the weed management treatments, application of imazethapyr at 15 DAS ($W_4$) recorded higher total weed density and dry weight and lower WCE. This might be due to the fact that in $W_4$ herbicide was applied only at 15 DAS; due to the slow initial development of cowpea, weed seeds emerge fast, grow luxuriantly by utilizing the available resources and gain competitive advantage over the crop resulting in higher biomass accumulation in weeds (Table 25). Higher weed dry weight resulted in lower WCE. The result is in accordance with the observation made by Kumavat *et al*. (2017) who observed that post emergence imazethapyr alone @ 100 g $ha^{-1}$ was not effective in reducing the weed density and dry weight. Kaur *et al*. (2016) also revealed that imazethapyr at 50 g $ha^{-1}$ was effective against BLW but not effective against sedges and grasses. It was been observed from the results that dried banana leaf mulch performed similar to pre emergence diclosulam in reducing the density and dry weight of weeds (Table 21 and 25). Dzomeku *et al*. (2009) reported that mulching with straw effectively suppress the weeds up to 3-6 WAT in tomato and hot pepper. Lower weed density, dry weight and higher WCE observed in $W_3$, $W_2$, $W_5$ and $W_6$ might be due to the better control of weeds achieved by the pre emergence herbicide diclosulam and dried banana leaf mulching followed by application of quizalofop-p-ethyl/ imazethapyr/ hand weeding at 25 DAS. The results clearly indicated that early stage weed control is essential to control the weeds in cowpea. Singh *et al*. (2009) reported that pre emergence diclosulam effectively control sedges, BLW and grasses and recorded higher WCE. Mulching with organic residues suppress the germination of weeds and significantly reduced the weed density and biomass (Akobundu, 1987; Shenk, 1994). Season long weed competition in weedy check caused 59.70 per cent reduction in pod yield in weed check. Among the weed management treatments, significantly lower WI was recorded by the treatment $W_3$, which might be due

to higher pod yield registered in the treatment resulting from the better control of weeds with high WCE.

Considering the interaction effect the treatment combinations $s_1w_6$, $s_1w_5$, $s_1w_3$ and $s_1w_2$ recorded lower values for absolute density, total weed density and dry weight and higher values for WCE at 15, 30 and 45 DAS. This might be due to the fact that in these treatments adoption of SSB destroyed the initial flushes of weeds prior to planting of seeds and subsequently emerged weeds were better controlled by the pre emergence herbicide diclosulam followed by hand weeding/ quizalofop-p-ethyl application at 25 DAS and dried banana leaf mulching followed by application of quizalofop-p-ethyl/ imazethapyr at 25 DAS. Tehria *et al*. (2015) also reported that SSB + pre emergence herbicide + hand weeding recorded lower weed dry weight and higher WCE in garden pea compared to pre emergence pendimethalin + hand weeding. The lowest WI was recorded by the treatment combination $s_1w_3$.

## 5.10 EFFECT OF WEED MANAGEMENT TREATMENTS ON SOIL ORGANIC CARBON CONTENT AND NUTRIENT AVAILABILITY

Seed bed manipulation did not have any significant effect on soil organic carbon content. However, weed management practices had significant effect on the soil organic carbon content of post-harvest soil. Data on post-harvest soil organic carbon content (Table 27) showed an increase in soil carbon content compared to initial soil status. This might be due to the addition of FYM uniformly to all plots @ 20 t ha$^{-1}$ of and also due to the addition of organic matter by the decay and decomposition of dried leaves and root nodules. The treatments with dried banana leaf mulch ($W_1$, $W_2$ and $W_3$) recorded higher organic carbon content than other treatments. Reason might be due to the fact that addition of dried banana leaf mulch @ 10 t ha$^{-1}$ in addition to 20 t ha$^{-1}$ of FYM, hence more organic matter was added to the soil. More the organic matter more will be the organic carbon. Compared to weedy check, weed management treatments recorded higher organic carbon. This might be due to the fact that better control of weeds provided a favourable environment for the crop to grow vigorously and release more amount of organic substances into the rhizosphere and also addition of organic matter by the decomposition of organic mulches. Raj (2019)

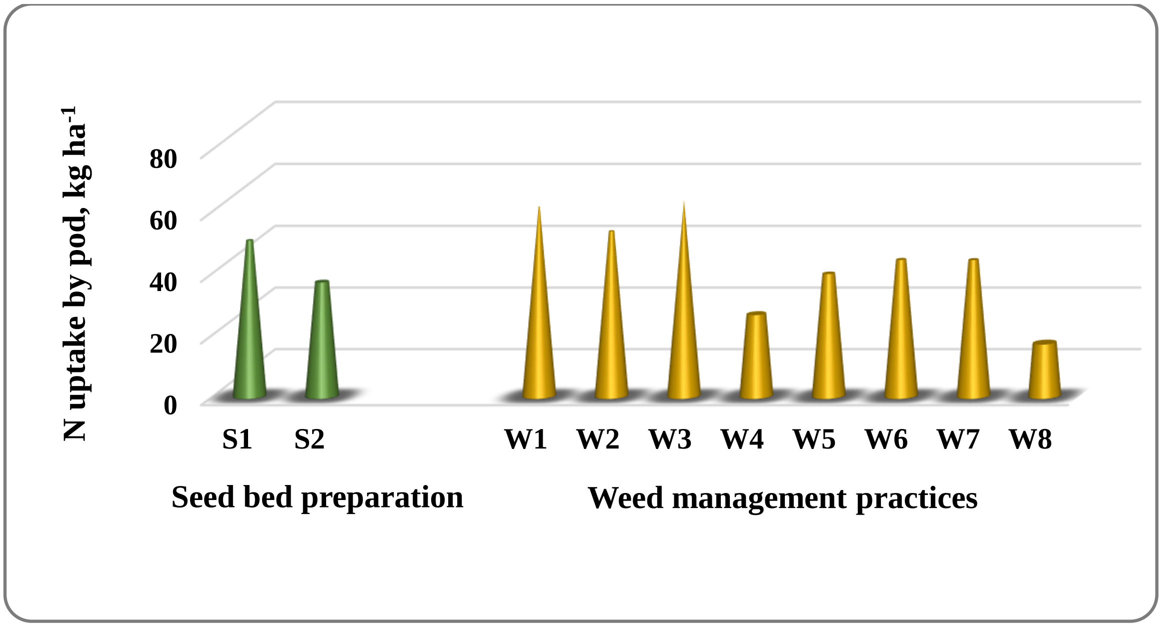


Fig 15. Effect of seed bed preparation and weed management practices on N uptake by pod

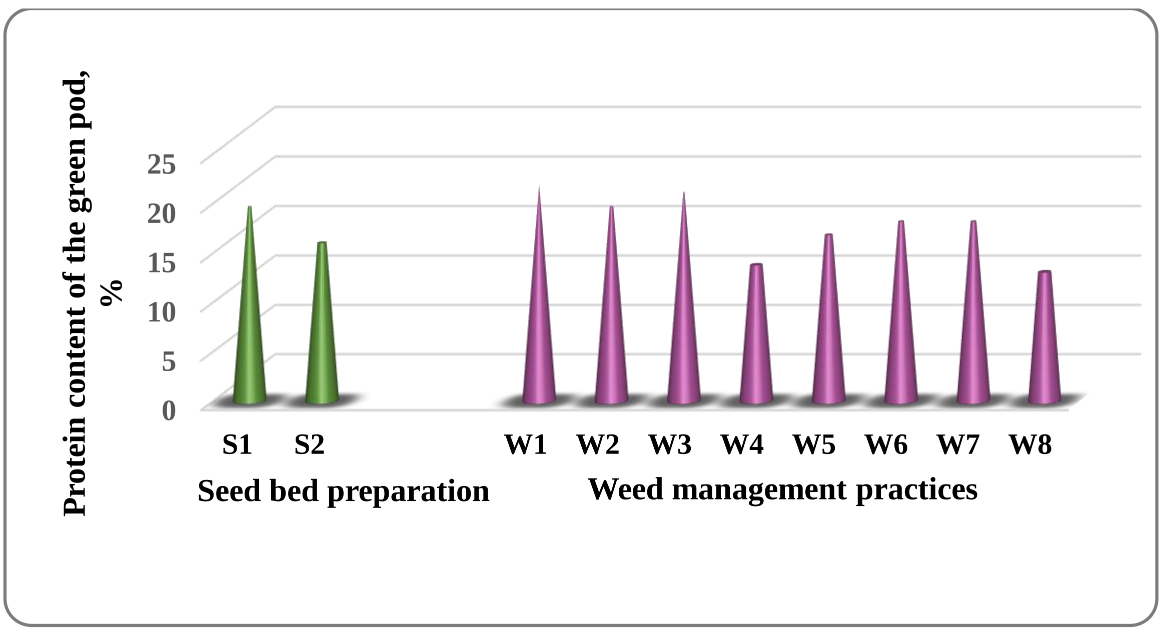


Fig 16. Effect of seed bed preparation and weed management practices on protein content of green pod

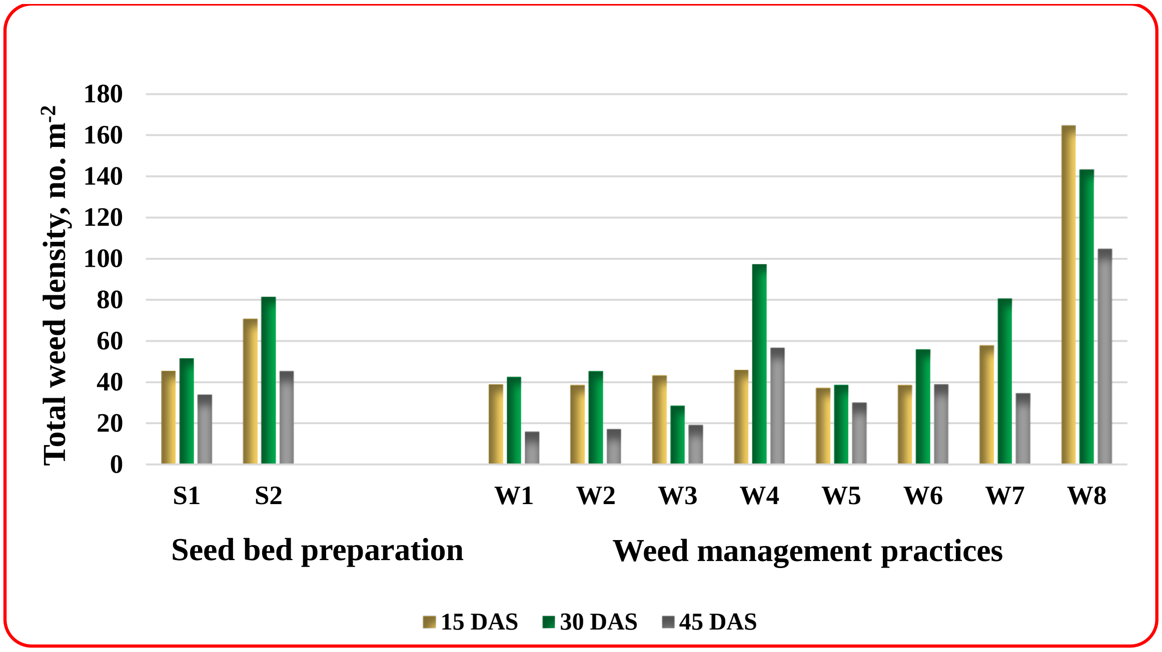


Fig 17. Effect of seed bed preparation and weed management practices on total weed density at 15, 30 and 45 DAS.

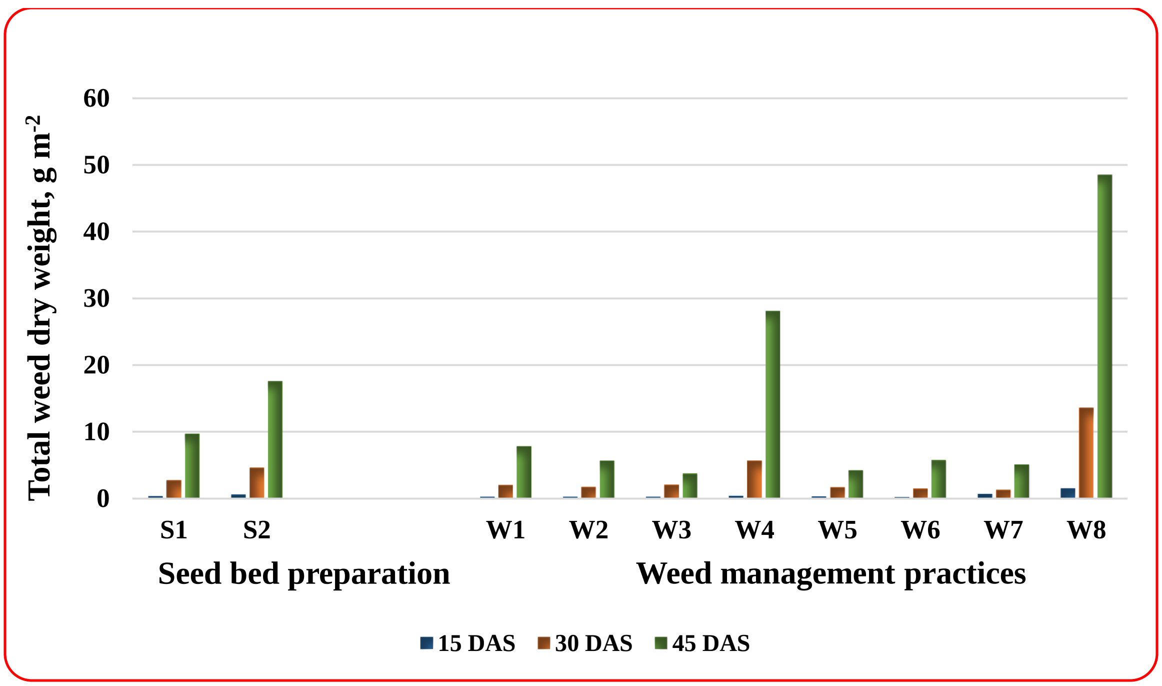


Fig 18. Effect of seed bed preparation and weed management practices on total weed dry weight at 15, 30 and 45 DAS.

opined that the enhanced organic carbon content of soil might be due to FYM addition and leaf fall. The result is in conformity with the findings of Raj and Syriac (2017) who reported that compared to weedy check, weed control treatments recorded higher organic carbon content in soil. Interaction between seed bed preparation and weed management practice did not have any significant effect.

Seed bed manipulation and weed management treatments significantly influenced the post-harvest available soil N, P and K status. Stale seed bed registered higher soil available N, P and K. This might be due to lesser removal of nutrients by weeds compared to normal seed bed (Fig. 23, 24 and 25). The result is in accordance with the observation made by Tehria *et al*. (2015) who observed that SSB recorded higher soil available N and P in post-harvest soil. The data on NPK status of post-harvest soil indicated that N and P availability was found to increase, but K status was found to decrease. Mitran *et al*. (2018) revealed that biological N fixation as well as inherent phosphorus use efficiency of legume crop, deep tap root system, increased P solubilization by root exudation and release of nutrients by the decomposition of crop residues enhanced the N and P availability. The decrease in K availability observed might be due to K uptake by the crop (Table 27) over the application. All weed management treatments recorded higher amount of available N, P and K in the post-harvest soil compared to weedy check might be due to the lesser depletion of nutrients by weeds (Fig. 23, 24 and 25). It has been observed from the data that the treatments with dried banana leaf mulch recorded higher soil available N, P and K. The reason might be due to lesser depletion of nutrients by weeds and also due to the fact that addition of organic materials to the soil might have stimulated the activity of nitrifying bacteria and increase the solubilization of fixed form of nutrients by the release of organic acids during the decay and decomposition of dried banana leaf. Dahiya and Malik (2002) reported that organic matter complexes with cations Fe and Al and reduces the P fixation and increases the P availability. Broschat (2007) reported that plots mulched with organic materials have high amount of P and K in soil. Alharbi (2017) also reported that mulching with organic materials enhanced the N, P and K status of soil.

Interaction effect was significant only for soil available P and K. Among the treatment combinations, $s_2w_8$ registered the lowest soil available P and K and N, though non-significant compared to other treatments. Severe infestation of weeds depletes 67.59, 5.10 and 5.10 kg $ha^{-1}$ of N, P and K from the soil which might be the reason for the lowest availability of nutrients in $s_1w_8$. Kumar *et al*. (2010) reported that effective management of weeds can significantly brought down the nutrient depletion by weeds and enhance the nutrient availability.

## 5.11 EFFECT OF WEED MANAGEMENT TREATMENTS ON NUTRIENT UPTAKE BY CROP

Nutrient uptake by crop was significantly influenced by seed bed manipulation. Stale seed bed recorded significantly higher total N, P and K uptake by crop. Adoption of SSB enhanced the total N, P and K uptake by 12.47, 33.25 and 8.71, per cent respectively over normal seed bed. Nutrient uptake by crop is directly related to nutrient content and DMP. Higher uptake of nutrients recorded in SSB might be due to higher DMP (Fig.5) and higher N, P and K content recorded in the treatment. Better control of weeds as evident from the data on total weed density, dry weight and WCE resulted in lesser weed competition which might have provided a favorable environment for the development of roots resulted in higher root fresh weight as well as root volume (Table 12 and 13). Better development of roots might have increased the foraging area of roots and enhanced the uptake of nutrients. Increased availability of nutrients due to minimum CWC also might have enhanced the uptake of nutrients in SSB. Tehria *et al*. (2015) reported that adoption of SSB significantly increased the nutrient uptake by crop over weedy check in pea.

Weed management practices also significantly influenced the NPK uptake by crop. Adoption of weed management practices increased the total N uptake by 86.88 per cent, P uptake by 64.74 per cent and K uptake by 32.34 per cent over control. Increased uptake of nutrients registered in weed control treatments might be due to the reduced CWC and nutrient removal by weeds. Reduced availability of nutrients due to season long CWC and higher nutrient removal by weeds might be the reason for the lowest uptake of nutrients by

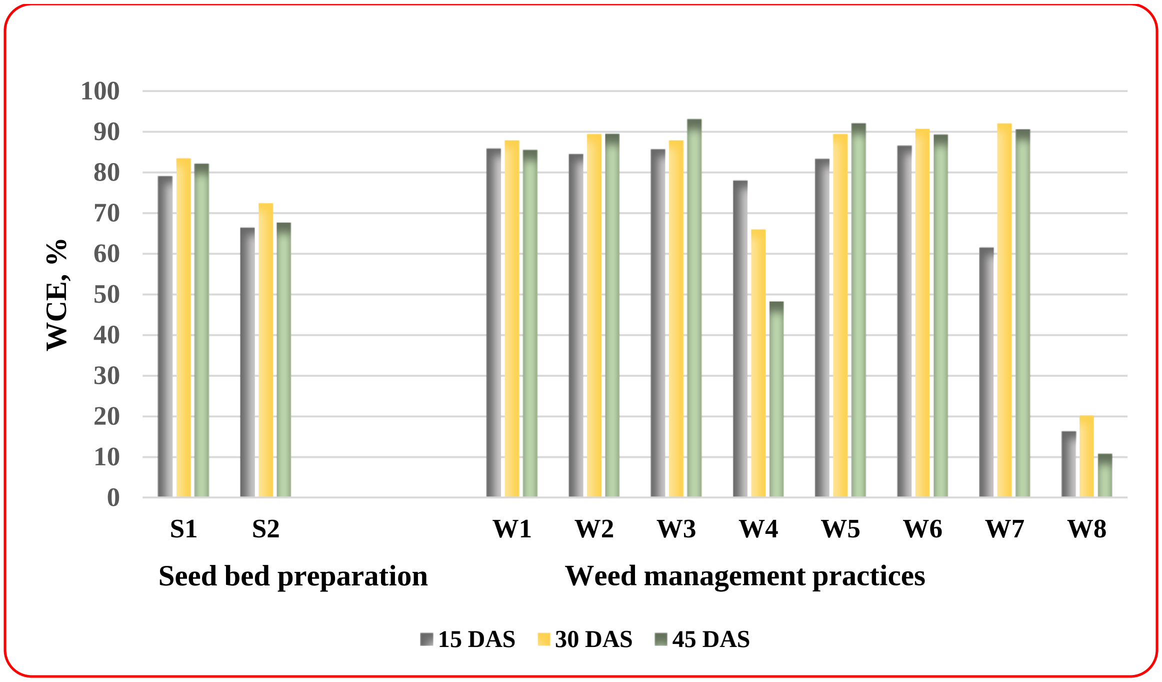


Fig 19. Effect of seed bed preparation and weed management practices on weed control efficiency (WCE) at 15, 30 and 45 DAS.

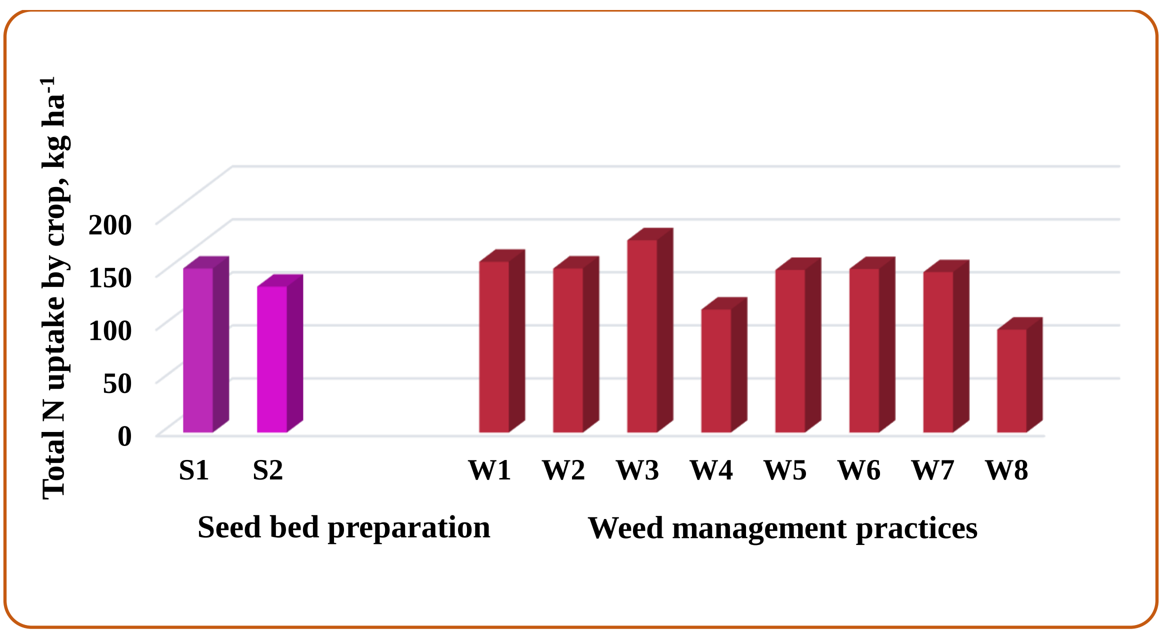


Fig 20. Effect of seed bed preparation and weed management practices on total N uptake by crop.


AT 10 DAS


AT 25 DAS


AT 45 DAS


AT 75 DAS

Plate 2: Performance of $s_1w_5$ treatment at different growth stages


AT 10 DAS


AT 25 DAS


AT 45 DAS


AT 75 DAS

Plate 3: Performance of $s_1w_6$ treatment at different growth stages


AT 10 DAS


AT 25 DAS


AT 45 DAS


AT 75 DAS

Plate 4: Performance of $s_1w_2$ treatment at different growth stages


AT 10 DAS


AT 25 DAS


AT 45 DAS


AT 75 DAS

Plate 5: Performance of $s_2w_8$ at different stages of crop growth


AT 10 DAS


AT 25 DAS


AT 45 DAS


AT 75 DAS

Plate 6: Performance of best treatment $s_1w_3$ at different growth stages

crop in weedy check. Weeds removed substantial amount of nutrients, if weeds are effectively controlled that much amount of nutrients removed by weeds can be utilized by the crop. In this experiment also 53.386 kg N, 4.226 kg P and 4.044 kg K were removed by weeds. Raj and Syriac, (2017) and Poornima *et al*. (2018) reported that severe competition for growth factors resulted in reduced uptake of nutrients by crop. It was revealed from the data that compared to application of imazethapyr at 15 DAS ($W_4$), banana leaf mulching followed by application of herbicides (imazethapyr or quizalofop-p-ethyl) ($W_2$ and $W_3$) or application of diclosulam followed by hand weeding or quizalofop-p-ethyl application ($W_5$ and $W_6$) recorded higher uptake of N, P and K by crop. This could be due to reduced CWC in the early as well as later stages of the crop growth resulted in higher DMP with higher uptake of nutrients. Bhutada and Bale (2015) reported that pre emergence pendimethalin followed by hand weeding at 40 DAS recorded higher uptake of N, P and K by chick pea compared to post emergence imazethapyr @75 g $ha^{-1}$. Among the weed management treatments, the highest total N and P uptake was reported in $W_3$ and K uptake in $W_6$ owing to the fact that higher WCE recorded in these treatments significantly reduced the CWC which might have reduced the nutrient removal by weeds and enhanced the availability of nutrients. Increased availability of nutrients and higher root growth (Table 12 and 13) allowed the crop to absorb and translocate adequate amount of nutrients which favoured the crop growth with higher nutrient content and DMP.

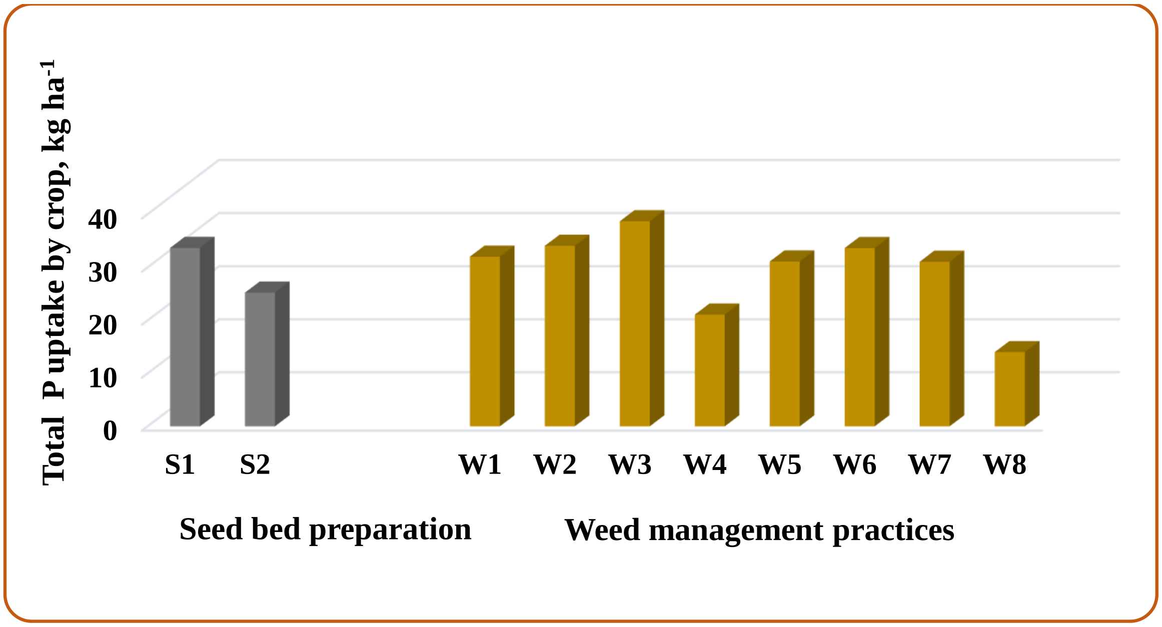


Fig 21. Effect of seed bed preparation and weed management practices on total P uptake by crop

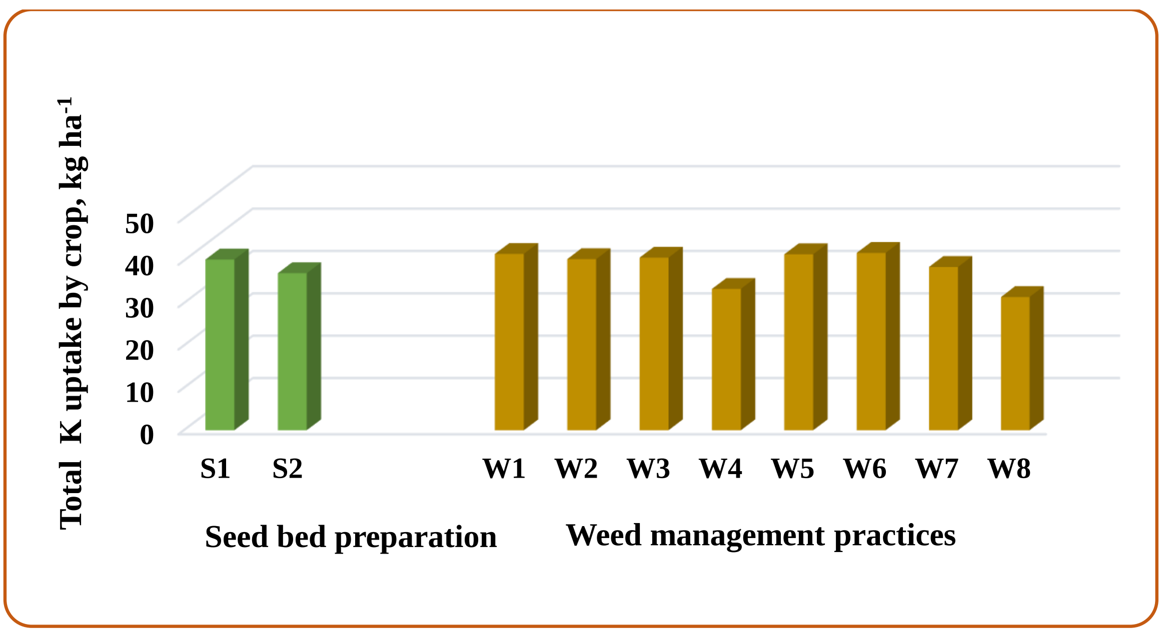


Fig 22. Effect of seed bed preparation and weed management practices on total K uptake by crop

## 5.12 EFFECT OF WEED MANAGEMENT TREATMENTS ON NUTRIENT UPTAKE BY WEEDS

Uptake of N P K by weeds was significantly influenced by weed management practices at both 30 and 45 DAS. Compared to SSB, normal seed bed recorded the highest uptake of N P K by weeds. By the adoption of SSB, a reduction in the NPK uptake by weeds to a tune of 25.51, 40.60 and 61.68 per cent, respectively at 30 DAS and to a tune of 48.93, 46.74 and 55.24 per cent, respectively at 45 DAS were observed. The percentage removal of K was found to be more compared to N and P. Higher density and dry weight of weeds (Table 21 and 25) recorded in normal seed bed was the reason for higher nutrient uptake in the treatment. Since nutrient uptake is the function of DMP and nutrient content, higher the dry weight of weeds, higher will be the nutrient uptake by weeds. Kumar *et al*. (2010) reported that normal seed bed recorded the highest N P K uptake by weeds in direct seeded rice. Rana *et al*. (1999) observed that weeds removed substantial amount of nutrients from the soil and adoption of weed management practices significantly improved the nutrient uptake by crop.

Weed management practices except $w_4$ recorded significantly lower uptake of NPK by weeds compared to weedy check both at 30 and 45 DAS. Adoption of weed control practices reduced the N removal by weeds to an extent of 59.4 to 90.7 per cent, P removal by weeds to an extent of 55.5 to 97.1 per cent and K removal to an extent of 66.4 to 92.8 per cent, respectively at 30 DAS. Percentage of N, P and K removal by weeds were reduced to an extent of 48.96 to 92.1, 50.4 to 96.1 and 55.6 to 94.6, respectively at 45 DAS. The result is in conformity with the observation made by Raj (2016) who reported that adoption of weed management practices significantly reduced the nutrient removal by weeds. Weedy check recorded the highest N P K uptake by weeds at both 30 and 45 DAS. This was the due to higher total weed density and weed dry weight observed in this treatment. Choudary *et al*. (2012) also reported that the highest removal of N P K (5.9, 2.8 and 7.1 kg ha$^{-1}$ respectively) was recorded in weedy check. The treatment $w_7$ (hand weeding treatment) recorded the lowest removal of nutrients by weeds at 30 DAS might be due to lower weed density and weed dry weight registered. Shalini *et al*. (2017) also observed

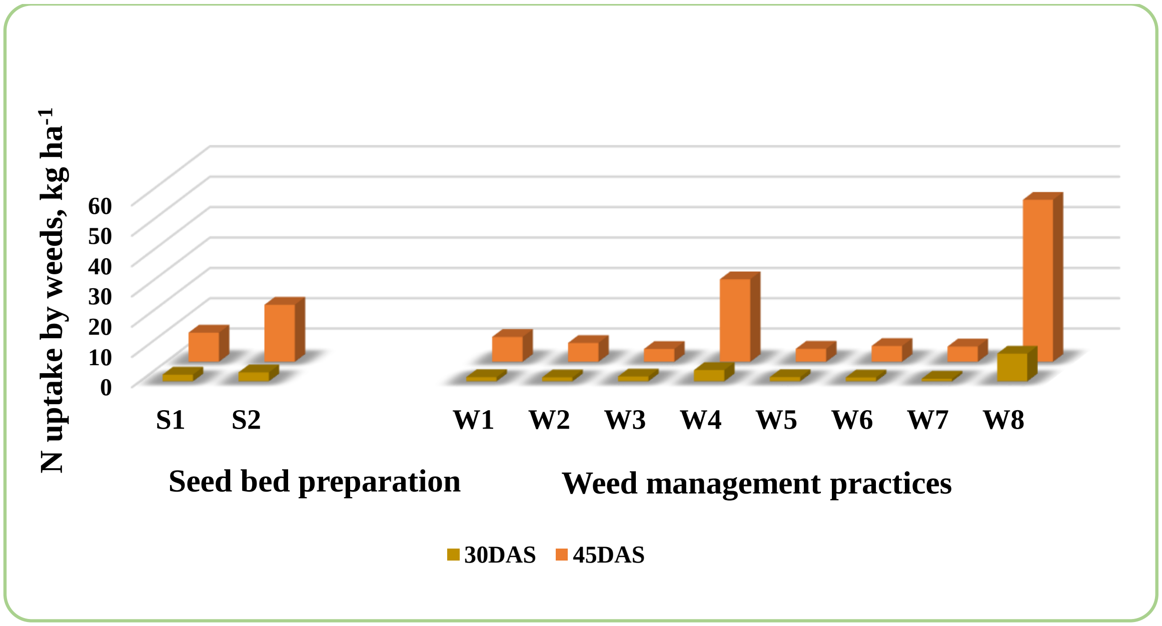


Fig 23. Effect of seed bed preparation and weed management practices on N uptake by weeds at 30 and 45 DAS

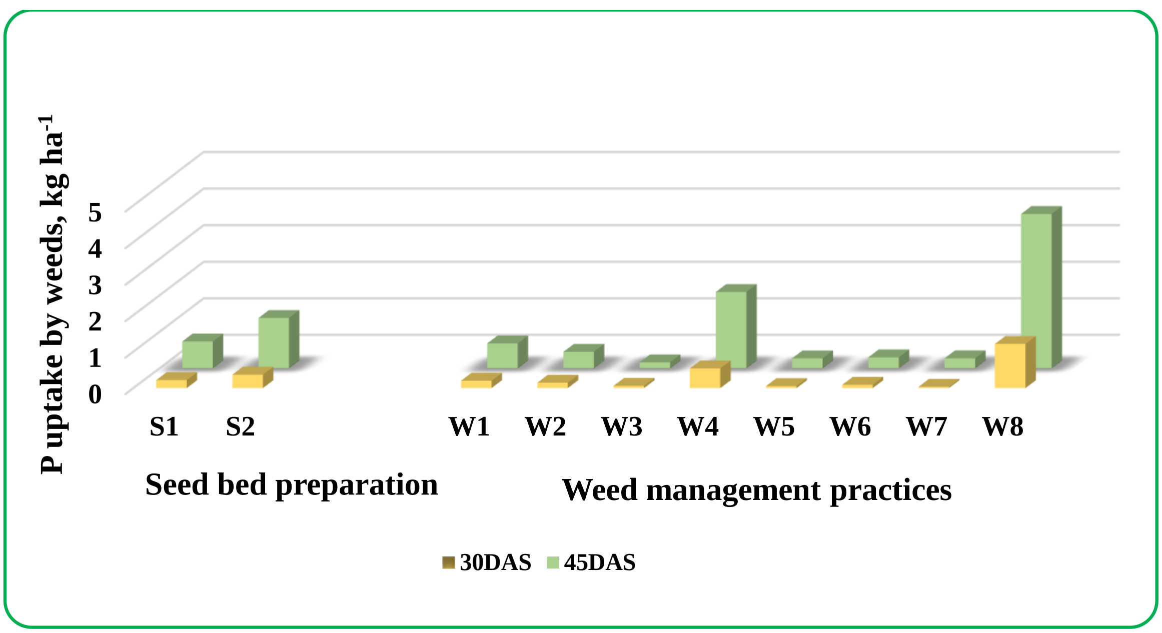


Fig 24. Effect of seed bed preparation and weed management practices on P uptake by weeds at 30 and 45 DAS

that hand weeding treatment recorded significant lower uptake of NPK by weeds in field pea. At 45 DAS, the lowest uptake of nutrients was observed in $W_3$. Mulching with dried banana leaf effectively suppresses the growth of weeds during the initial stages of crop growth and the later emerged grassy weeds was effectively controlled by post emergence quizalofop-p-ethyl at 25 DAS. The lowest density and dry matter accumulation of weeds (Fig. 17 and 18) observed in the treatment resulted in reduced uptake of nutrients by weeds. Samant and Mishra (2014) revealed that post emergence quizalofop-p-ethyl @ 1 kg $ha^{-1}$ at 15 DAS was found effective in minimizing the N P and K removal by weeds to an extent of 91.2, 84.1 and 89.7 per cent, respectively. Among the weed management treatments, $w_4$ recorded the highest uptake of nutrients by weeds at both the stages of observation. This could be attributed to higher dry matter accumulation of weeds due to the poor control of weeds in the treatment. The result is in accordance with the observation made by Singh *et al*. (2014) who observed that application of imazethapyr at 15 DAS recorded higher dry matter of weeds due to the poor control of weeds in mung bean. Kaur *et al*. (2016) also reported that imazethapyr was found effective only in controlling BLW and not effective against grasses and sedges.

The interaction was also found significant. At both stages of observation $s_2w_8$ recorded higher uptake of nutrients by weeds. This was due to higher density of weeds and higher dry matter accumulation (Table 21a and 25a) registered in this treatment.

## 5.13 EFFECT OF WEED MANAGEMENT PRACTICES ON DEHYDROGENASE AND UREASE ENZYME ACTIVITY

Dehydrogenase enzyme activity which indicates the microbial respiratory activity and urease enzyme activity which plays a major role in the hydrolysis of urea to ammonia and carbon di oxide is considered as the biological indicators of soil health. Seed bed manipulation had significant effect on the dehydrogenase enzyme activity at 15 and 30 DAS, however urease activity did not have any significant effect at all three stages of observation. Stale seed bed recorded higher dehydrogenase enzyme activity both at 15 DAS and 30 DAS. Higher bacterial activity as evident from the data on total number of nodules and effective nodules (Table 11) might be the reason for higher dehydrogenase enzyme activity in SSB.

Weed management treatments significantly influenced the dehydrogenase and urease enzyme activity. At all the three stages of observation, compared to weedy check, weed management treatments recorded higher dehydrogenase and urease enzyme activity. This indicated that applied herbicides and dried banana leaf mulching did not have any negative impact on soil health. Raj (2016) also reported that compared to weedy check herbicide treated plots and hand weeding treatment recorded higher urease and dehydrogenase enzyme activity. The variations in the urease enzyme activity observed among the treatments might be due to changes in soil pH and soil temperature. Yang *et al*. (2006) reported that urease activity in soil depends on the microbial community, soil pH and soil temperature. The treatments with dried banana leaf mulch recorded higher dehydrogenase enzyme activity compared to other treatments might be due to higher substrate availability. Dehydrogenase enzyme activity is highly related to the organic matter content in the soil. Adak *et al*. (2014) and Basak *et al*. (2013) reported that dehydrogenase enzyme activity increased with the availability of organic matter.

The interaction between seed bed preparation and weed management practices was significant only at 30 DAS. The treatment combination $s_2w_8$ recorded the lowest dehydrogenase and urease enzyme activity at all the three stages of observation. This might be due to lesser substrate availability due to severe weed infestation and also due to the lesser availability of nutrients. Manjaiah and Singh (2001) and Koyama *et al*. (2013) opined that enzyme activity increased with the availability of nutrients.

## 5.14 EFFECT OF WEED MANAGEMENT PRACTICES ON ECONOMICS

Economic assessment of weed management treatments is of great importance for its applicability in the farmer field. Compared to normal seed bed, SSB recorded higher net income of ₹ 37838.6 $ha^{-1}$ and B: C ratio of 1.43 compared to normal seed bed which recorded a net income of ₹ 21821.7 and B: C ratio of 1.32. Higher net income and B: C ratio recorded in SSB might be due to higher green pod yield (Fig. 14) registered in the treatment. Better control of weeds in the initial stages of crop growth provided a weed free

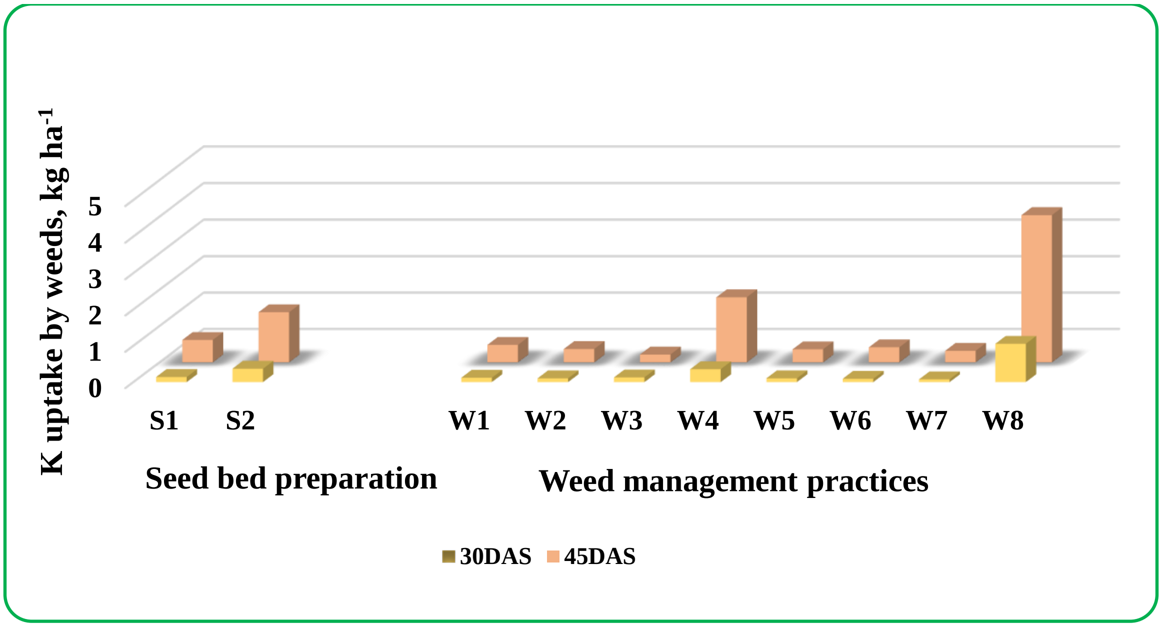


Fig 25. Effect of seed bed preparation and weed management practices on K uptake by weeds at 30 and 45 DAS

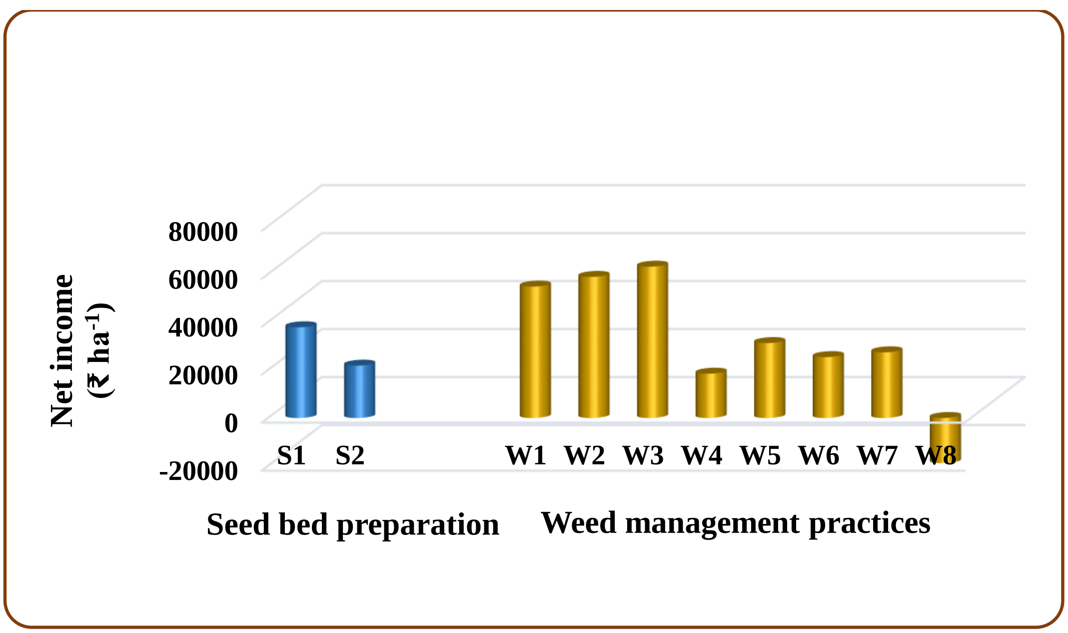


Fig 26. Effect of seed bed preparation and weed management practices on net income

environment which would allow the crop to grow without any competition and utilized the resources efficiently. Increased photosynthesis and better translocation of photosynthates from source to sink resulted in higher yield with higher net income and B:C ratio in SSB. The result is in accordance with the observation made by Ravikiran *et al*. (2019) who reported that SSB recorded higher net income and B:C ratio in upland rice compared to normal seed bed.

Weed management practices also significantly influenced the net income and B:C ratio. Adoption of weed management practices enhanced the net income from ₹18, 475.0 ha$^{-1}$ to 63,121.0 ha$^{-1}$ compared to weedy check. This might be due to the better reduction of weed density and weed dry weight which reduced the CWC that helped to improve the vigour of the crop and increased the uptake of nutrients which ultimately resulted in higher number of pods per plant and higher green pod yield. Higher pod yield resulted in higher net income and B: C ratio. Among the weed management practices $W_3$ recoded the highest net income and B: C ratio. This was because of the better control of weeds right from seeding stage to 25 DAS by dried banana leaf mulch thereafter by the better control of grassy weeds by the application of quizalofop-p-ethyl at 25 DAS. Nair (2018) reported that mulching with polyethene material and straw significantly decreased the weed density and enhanced the tomato fruit yield, net returns and B: C ratio. Singh *et al*. (2018) reported that pre emergence pendimethalin *fb* quizalofop-p-ethyl @ 75 g ha$^{-1}$ recorded higher net returns and B:C ratio in elephant foot yam. Post emergence imazethapyr @ 50 g ha$^{-1}$ recorded the lowest net income and B: C ratio among the weed management treatments. This was due to the fact that higher CWC due to the poor control of weeds resulted in the production of lesser number of pods per plant and green pod yield.

Interaction effect also had significant effect on net income and B:C ratio. The treatment combination $s_1w_3$ recorded the highest net income and B:C ratio might be due to the combined effect of SSB, mulching and post emergence application of quizalofop-p-ethyl in suppressing the weeds and favouring the crop growth resulting in higher green pod yield.

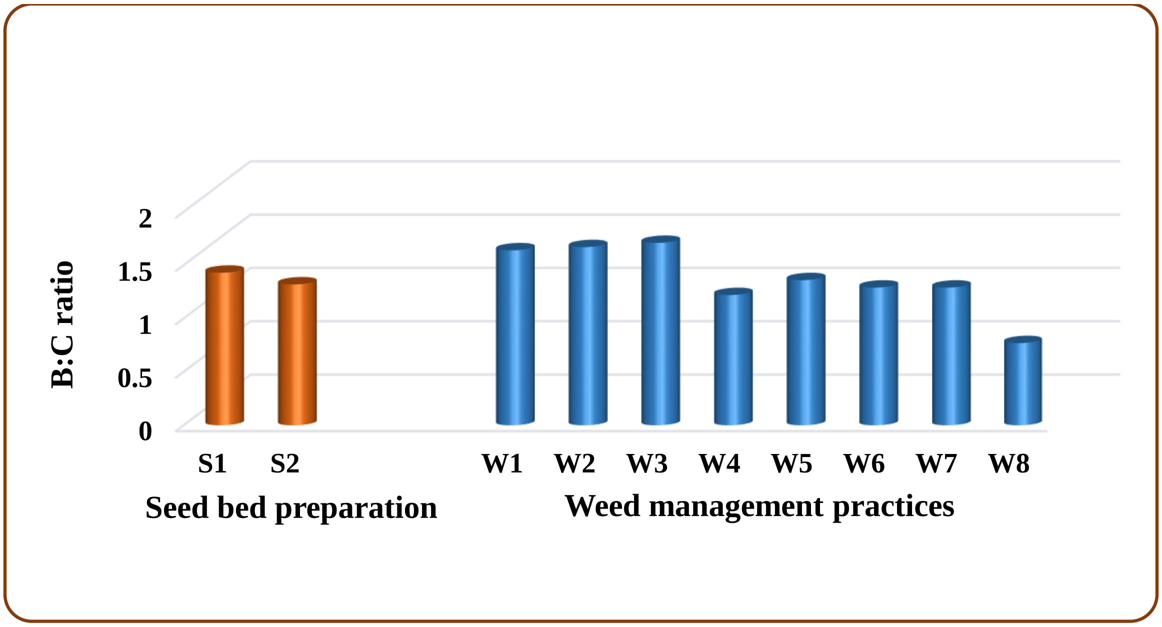


Fig 27. Effect of seed bed preparation and weed management practices on B:C

# SUMMARY

# 6. SUMMARY

The research work entitled "Integrated weed management in bush type vegetable cowpea (*Vigna unguiculata* subsp. *unguiculata* (L.) Verdcourt) was carried out with an objective to find out the cost-effective weed management practice in bush type vegetable cowpea. The experiment was taken up during *Kharif* season 2019 at Coconut Research Station, Balaramapuram. Significant findings of the experiment are summarized below.

The field experiment was laid out in factorial randomized block design with two factors.

Factor A- seed bed preparation with two treatments, $S_1$- stale seed bed and $S_2$- normal seed bed (no stale). Factor B - weed management practices with eight treatments, *viz*., $W_1$- dried banana leaf mulch @ 10 t ha$^{-1}$ alone , $W_2$- dried banana leaf mulch @ 10 t ha$^{-1}$ *fb* post emergence imazethapyr @ 50 g ha$^{-1}$ at 25 DAS, $W_3$- dried banana leaf mulch @ 10 t ha$^{-1}$ *fb* post emergence quizalofop-p-ethyl @ 50 g ha$^{-1}$ at 25 DAS, $W_4$- post emergence imazethapyr @ 50 g ha$^{-1}$ at 15 DAS, $W_5$- pre emergence @ 12.5 g ha$^{-1}$ *fb* post emergence quizalofop-p-ethyl @ 50 g ha$^{-1}$ at 25 DAS, $W_6$- pre emergence diclosulam @ 12.5 g ha$^{-1}$ *fb* hand weeding at 25 DAS, $W_7$- hand weeding at 20 and 40 DAS, $W_8$- weedy check.

Seed bed preparation had significant effect on growth parameters, *viz*., plant height at 20 and 40 DAS, number of leaves per plant at 20, 40 and 60 DAS, number of branches per plant at 20 DAS and DMP at 20, 40 and 60 DAS. Stale seed bed recorded higher values for all the above parameters described.

Weed management practices also had significant effect on growth parameters *viz*., plant height at 20 and 40 DAS, number of branches per plant at 20 DAS and leaves per plant and DMP at 20, 40 and 60 DAS. At 20 DAS, the highest plant height was observed in $W_2$, higher number of leaves in $W_1$ and branches per plant and DMP in $W_3$. However, at 40 DAS, $W_1$ recorded higher values for plant height and $W_3$ recorded higher number of leaves and DMP and at 60 DAS, $W_2$ and $W_6$ recorded higher number of leaves per plant and $W_3$ recorded the highest DMP.

Interaction effect was significant for plant height only at 20 DAS and number of leaves per plant at 60 DAS. At 20 DAS, the highest plant height was noted in $s_1w_2$ and at 60 DAS $s_1w_6$ recorded the highest number of leaves per plant.

Among the seed bed preparation, SSB recorded the highest root volume and root fresh weight and among the weed management practices, $W_3$ recorded the highest root fresh weight at all stages. However, the treatments $W_1$, $W_3$ and $W_6$ recorded the highest root volume at 20 DAS, $w_2$ at 40 DAS and $W_1$, $W_3$ and $W_7$ at 60 DAS.

Interaction effect was significant only at 20 and 60 DAS for root volume and root fresh weight. At 20 DAS, $s_1w_2$ recorded the highest root fresh weight and at 60 DAS $s_1w_3$ recorded the highest root fresh weight. However, the treatment combinations, $s_1w_1$, $s_1w_3$ and $s_1w_6$ were recorded the highest root volume at 20 DAS and $s_1w_1$ recorded the highest root volume at 60 DAS.

Among physiological parameters, *viz.*, LAI, CGR and total chlorophyll content at 60 DAS were favourably influenced by seed bed preparation. Stale seed bed recorded the highest CGR at both the time intervals (20 - 40 DAS and 40 - 60 DAS), LAI at all the three stages of observation and total chlorophyll content at 60 DAS.

Between the weed management practices, LAI was the highest in $W_1$, $W_3$ and $W_2$ at 20, 40 and 60 DAS, respectively. The treatment $W_3$ recorded higher values for CGR at both time intervals (20 - 40 DAS and 40 - 60 DAS) and $W_5$ recorded higher RGR values at both time intervals (20 - 40 DAS and 40 - 60 DAS). The treatment $W_3$ recorded higher total chlorophyll at 40 DAS and $W_2$ recorded higher total chlorophyll content at 60 DAS.

Interaction effect had significant effect only on LAI and total chlorophyll content at 20 and 40 DAS. The treatment combinations $s_1w_1$ and $s_1w_2$ recorded the highest LAI at 20 DAS and $s_1w_2$ recorded the highest LAI at 60 DAS. The total chlorophyll content was found to be the highest in $s_2w_3$ at 40 DAS and in $s_1w_2$ at 60 DAS.

Stale seed bed recorded significantly higher total nodules per plant (12.00), effective nodules per plant (7.08) and nodule fresh weight per plant (0.833).

Among the weed management practices, $w_6$ recorded the highest total nodules per plant and effective nodules per plant. However, nodule fresh weight was the highest in $W_3$.

The interaction effect was significant for all nodule parameters. The total number of nodules per plant and effective nodules per plant were found to be the highest in $s_1w_6$ and nodule fresh weight per plant in $s_1w_3$.

The analysis of weed vegetation parameters disclosed that grasses were the dominating weed flora with respect to relative density and absolute density followed by BLW. The population of sedges was comparatively low.

Seed bed preparation significantly influenced the absolute density of grasses and BLW and SSB recorded significantly lower density of grasses and BLW at all the three stages of observation.

Among the weed management practices $w_3$ registered the lowest absolute density of grasses at all the three stages of observation. However, in the case of BLW $W_5$, $W_3$ and $W_2$ recorded the lowest absolute density at 15, 30 and 45 DAS, respectively. Absolute density of sedges was significant only at 45 DAS and $W_5$ recorded the highest absolute density of sedges.

Interaction effect was also significant for the absolute density of grasses and BLW at all the three stages of observation. Among the interaction, $s_1w_5$ registered the lowest absolute density of grasses at 15 DAS, $s_1w_1$ and $s_1w_2$ at 30 DAS and $s_1w_3$ at 45 DAS. At 15 DAS, the lowest absolute density of BLW was recorded in $s_1w_5$ and at 30 and 45 DAS, it was the lowest in $s_1w_1$ and $s_1w_2$, respectively.

Stale seed bed significantly reduced the total density of weeds compared to no stale seed bed.

Amongst the weed management practices, $w_2$ and $w_6$ recorded the lowest total weed density at 15 DAS and $W_3$ and $W_1$ recorded the lowest total weed density at 30 and 45 DAS, respectively. Weedy check recorded significantly higher total density of weeds at all the three stages of observation.

The interaction effect was also significant and the treatment combination, $s_1w_5$ recorded the lowest total density of weeds at 15 DAS and $s_1w_2$ at both 30 and 45 DAS, respectively.

Stale seed bed registered significantly lower total dry weight of weeds at all the three stages of observation.

Total dry weight of weeds was also significantly influenced by weed management practices. Weedy check registered the highest total dry weight of weeds at all the three stages of observation. However, $W_6$ registered the lowest total weed dry weight at 15 DAS, $W_7$ at 30 DAS and $W_3$ at 45 DAS.

Interaction effect was also significant and the treatment combination $s_1w_6$ recorded the lowest weed dry weight at 15 and 45 DAS, and $s_1w_7$ at 30 DAS.

Stale seed bed recorded significantly higher WCE at 15, 30 and 45 DAS compared to normal seed bed.

Weed control efficiency varied due to weed management practices significantly. Among the treatments, $W_6$ recorded the highest WCE at 15 DAS, $W_7$ at 30 DAS and $W_3$ at 45 DAS, respectively.

Interaction effect was also significant and the treatment combination $s_1w_6$ recorded the highest WCE at 15 and 45 DAS and $s_1w_7$ at 30 DAS.

Seed bed preparation significantly influenced the N, P, K uptake by weeds at 30 and 45 DAS. Normal seed bed recorded the highest uptake of N, P and K by weeds at both the stages.

Among the weed management practices weedy check recorded the highest N, P, K uptake at both 30 and 45 DAS. The treatments $W_7$ and $W_3$ recorded the lowest N, P, K uptake by weeds at 30 and 45 DAS, respectively.

Interaction was significant and the treatment combination $s_1w_7$ recorded the lowest weed uptake at 30 DAS and $s_1w_6$ at 45 DAS, respectively.

Dehydrogenase enzyme activity was significantly influenced by seed bed preparation and SSB ($S_1$) registered significantly higher values at all the three stages of observation. Seed bed preparation did not have any significant effect on urease activity.

Dehydrogenase and urease enzyme activity were significantly influenced by weed management practices. Amongst the weed management practices, $W_4$ recorded higher dehydrogenase enzyme activity at 15 DAS. The treatments $W_3$ and $W_1$ recorded higher dehydrogenase enzyme activity at 30 and 45 DAS, respectively. In the case of urease enzyme activity, the treatments $W_6$, $W_5$ and $W_7$ recorded higher values at 15, 30 and 45 DAS, respectively.

Interaction effect was significant only at 45 DAS for both dehydrogenase and urease enzyme activity. The treatment combination $s_1w_3$ recorded the highest dehydrogenase enzyme activity and $s_2w_5$ recorded the highest urease enzyme activity.

Total N, P and K uptake by crop was significantly influenced by seed bed preparation and SSB recorded higher N, P and K uptake by crop than normal seed bed.

Weed management practices also significantly influenced the N, P and K uptake by crop. Among the weed management practices, $W_3$ recorded the highest total N and P uptake by crop and K uptake by $W_6$. Weedy check ($W_8$) registered the lowest uptake by crop.

Interaction effect was also significant and the treatment combination $s_1w_3$ recorded the highest N and P uptake and $s_1w_6$ recorded the highest K uptake by crop

Stale seed bed recorded significantly higher number of green pods per plant, pod length and pod weight and recorded lesser number of days to reach 50 per cent flowering.

Weed management practices also significantly influenced the yield attributes, *viz.*, number of pods per plant, pod girth, pod length, pod weight. The treatment $W_3$ recorded higher number of pods per plant (44.0) and pods with the highest girth and weight. However, the pod length was recorded the highest in $W_7$.

Interaction was significant only for number of pods per plant and pod weight. The treatment combination $s_1w_3$ recorded the highest number of pods per plant (44.7) and pod weight among the treatments.

Green pod yield per plant, green pod yield per hectare, harvest index and weed index were significantly influenced by seed bed preparation. Seed bed preparation did not have any significant effect on haulm yield. Stale seed bed recorded the highest green pod yield per plant, green pod yield per hectare, HI and lower WI compared to normal seed bed.

Weed management practices significantly influenced the green pod yield per plant and per hectare, haulm yield per plant and per hectare, HI and WI. The treatment $W_3$

registered the highest green pod yield per plant (110. 73 g) and green pod yield per hectare (7589.0 kg), HI (0.278) and the lowest WI (1.81 %). However, the highest haulm yield per plant and per hectare was recorded in the treatment $W_6$. Weedy check registered the lowest green pod yield per plant and per hectare and HI. Season long weed infestation caused a yield reduction of 59.70 per cent in bush type vegetable cowpea.

The interaction was significant for both green pod yield per plant and per hectare, haulm yield per plant and per hectare, HI and WI. The treatment combination $s_1w_3$ recorded the highest green pod yield per plant (119.66 g) and per hectare yield (7731.7 kg), HI (0.279) and the lowest WI (0.00). However, the haulm yield was recorded the highest in $s_1w_6$.

Protein content of the pods was significantly influenced by seed bed preparation and SSB recorded higher protein content (19.69 per cent) compared to normal seed bed.

Similarly, protein content was significantly influenced by weed management practices. Among the treatments, $W_1$ recorded the highest protein content in pods which was statistically on par with $W_2$ and $W_3$.

Interaction effect did not have any significant effect on protein content of the pods.

Organic carbon content of the soil was not significantly influenced by seed bed preparation. However, soil available N, P and K content of post-harvest soil was significantly influenced by seed bed preparation. Stale seed bed registered higher soil available N, P and K compared to normal seed bed.

Weed management practices also had a significant effect on post-harvest nutrient status of soil. The treatment $W_2$ registered the highest soil organic carbon, available soil P and K. However, the available soil N was recorded the highest in $W_3$. Weedy check registered the lowest soil organic carbon, available soil N, P and K.

The interaction effect was significant only for available soil P and K. The treatment combinations $s_1w_1$ registered the highest available soil P and $s_1w_6$ recorded the highest soil available K among the treatment combinations.

Stale seed bed recorded the highest net income of ₹37,838.6 $ha^{-1}$ and B:C ratio of 1.43. Among the weed management treatments, $W_3$ recorded the highest net income of ₹

63,121.0 ha$^{-1}$ and B:C ratio of 1.71. Among the interaction effect, the treatment combination $s_1w_3$ recorded the highest net income (₹ 64,775.0) and B:C ratio of 1.72.

Hence based on the weed, growth, physiological, nodule and yield parameters, green pod yield, harvest index and weed index, SSB + dried banana leaf mulch @ 10 t ha$^{-1}$ *fb* application of quizalofop-p-ethyl @ 50 g ha$^{-1}$ on 25 DAS could be adjudged as the best weed management practice for getting higher net income and B:C ratio in bush type vegetable cowpea.

FUTURE LINE OF WORK

1. For the confirmation of results, same experiment can be repeated for two or more seasons
2. Studies can be taken up to find out the allelopathic effect of dried banana leaf mulch on weeds.

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# ABSTRACT

# ABSTRACT

The study entitled "Integrated weed management in bush type vegetable cowpea (*Vigna unguiculata* subsp. *unguiculata* (L.) Verdcourt) was carried out during the period 2018-2020, at College of Agriculture, Vellayani, Thiruvananthapuram, Kerala with an objective to find out a cost-effective weed management practice for bush type vegetable cowpea.

The field experiment was undertaken at Coconut Research Station, Balaramapuram, Thiruvananthapuram, Kerala during *Kharif* 2019 (May to August 2019). The experiment was conducted in RBD with two factors, first factor being seed bed preparation (S), *viz*., stale seed bed ($S_1$) and normal seed bed ($S_2$) and second factor, weed management practices (W) *viz*., dried banana leaf mulch @ 10 t ha$^{-1}$ alone ($W_1$), dried banana leaf mulch @ 10 t ha$^{-1}$ *fb* post emergence imazethapyr @ 50 g ha$^{-1}$ at 25 DAS ($W_2$), dried banana leaf mulch @ 10 t ha$^{-1}$ *fb* post emergence quizalofop-p-ethyl @ 50 g ha$^{-1}$ at 25 DAS ($W_3$), post emergence imazethapyr @ 50 g ha$^{-1}$ at 15 DAS ($W_4$), pre emergence diclosulam @ 12.5 g ha$^{-1}$ *fb* post emergence quizalofop-p-ethyl @ 50 g ha$^{-1}$ at 25 DAS ($W_5$), pre emergence diclosulam @ 12.5 g ha$^{-1}$ *fb* hand weeding at 25 DAS ($W_6$), hand weeding at 20 and 40 DAS ($W_7$) and weedy check ($W_8$). The variety used for the study was Bhagyalakshmy.

Results of the experiment revealed that stale seed bed (SSB) had significant effect on crop growth parameters, physiological parameters, total chlorophyll content and nodule parameters at different stages of crop and it recorded the lowest total weed density and nutrient removal by weeds, the highest WCE, total plant uptake, yield, net income, harvest index, B: C ratio and the lowest weed index.

Weed management practices significantly influenced the growth, physiological, and nodule parameters at different stages of crop growth. The treatments $W_2$, $W_3$ and $W_1$ recorded the lowest total weed density and the treatments $W_6$, $W_7$ and $W_3$ recorded the highest weed control efficiency at 15, 30 and 45 DAS, respectively. The N, P and K uptake by weeds at 30 and 45 DAS was recorded the lowest in $W_7$ and $W_3$, respectively. Results

on dehydrogenase and urease enzyme activity revealed that the tested herbicides, *viz.*, diclosulam, imazethapyr and quizalofop-p-ethyl did not have any negative impact.

The treatment $w_3$ recorded the highest N and P uptake by crop, pods per plant (44.00), pod length (15.23 cm), pod girth (2.20 cm), pod weight (2.56 g), green pod yield per plant (110.73 g) and per hectare (7589.0 kg), net income (₹63,121.0), B:C ratio (1.71) and the lowest weed index (1.68 per cent). The treatment $w_6$ recorded the highest K uptake by crop and protein content the highest in $W_1$.

The interaction effect was significant for leaves per plant at 60 DAS, root fresh weight, root volume and LAI at 20 and 60 DAS, chlorophyll content at 40 and 60 DAS and nodule parameters at 50 per cent flowering stage.

The lowest total weed density was registered in $s_1w_5$, $s_1w_3$ and $s_1w_2$ at 15, 30 and 45 DAS, respectively. The treatment $s_1w_6$ recorded the highest weed control efficiency at 15 and 45 DAS and $s_1w_7$ at 30 DAS. The weed index was recorded the lowest in $s_1w_3$. At 30 and 45 DAS, $s_2w_8$ recorded the highest N, P and K uptake by weeds.

The number of green pods per plant (44.7), pod weight (2.68, g), pod yield per plant (119.66 g) and per hectare (7731.7 kg), harvest index (0.279), net income (₹ 64,775.0) and B: C ratio (1.72) were found the highest in $s_1w_3$. The protein content was recorded the highest in $s_1w_1$.

Hence, considering the WCE, yield, weed index, HI, net income and B:C ratio, stale seed bed + dried banana leaf mulch 10 t ha$^{-1}$ *fb* application of quizalofop-p-ethyl @ 50 g ha$^{-1}$ at 25 DAS ($s_1w_3$) could be adjudged as the cost effective and the best weed management practice for higher green pod yield and net return in bush type vegetable cowpea.

# APPENDIX

# APPENDIX 1

## Weather data during the crop season (May 2019- August 2019)

| Standard week | Temperature ($^0C$) | | RH (%) | | Rainfall (mm) | No. of rainy days |
|---|---|---|---|---|---|---|
| | Maximum | Minimum | Maximum | Minimum | | |
| 20 | 34.37 | 18.78 | 78.71 | 66.70 | - | - |
| 21 | 34.31 | 17.92 | 85.85 | 73.10 | 29.20 | 2 |
| 22 | 34.38 | 18.35 | 81.57 | 68.60 | 10.40 | 1 |
| 23 | 32.44 | 16.51 | 91.42 | 81.60 | 156.20 | 6 |
| 24 | 31.55 | 16.42 | 91.14 | 81.20 | 87.00 | 6 |
| 25 | 31.30 | 16.74 | 87.14 | 77.14 | 25.60 | 2 |
| 26 | 32.05 | 17.60 | 85.71 | 75.28 | - | - |
| 27 | 32.31 | 17.28 | 86.71 | 77.14 | 56.80 | 4 |
| 28 | 31.97 | 16.30 | 89.85 | 79.00 | 19.80 | 2 |
| 29 | 31.08 | 15.40 | 92.71 | 81.57 | 112.60 | 5 |
| 30 | 31.08 | 15.64 | 90.50 | 82.42 | 6.20 | 2 |
| 31 | 31.78 | 16.57 | 92.00 | 77.57 | 71.00 | 1 |
| 32 | 30.37 | 14.57 | 85.00 | 81.71 | 248.80 | 6 |
| 33 | 30.88 | 15.32 | 82.14 | 76.57 | 14.60 | 2 |
| 34 | 31.30 | 15.71 | 87.00 | 77.00 | 80.80 | 3 |