CROP ESTABLISHMENT METHODS AND WEED MANAGEMENT ON PRODUCTIVITY OF COWPEA [*Vigna unguiculata* (L.) Walp.]

By

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(2019-11-125)

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THESIS

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DECLARATION

I, Ayisha Jezla P.(2019-11-125) hereby declare that the thesis entitled **"Crop establishment methods and weed management on productivity of cowpea[*Vigna unguiculata* (L.) Walp.]"**is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed the basis for the award to me any degree, diploma, fellowship or other similar title, of any other university or society.

Vellanikkara

Date:27-4-2022

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CERTIFICATE

Certified that the thesis entitled **"Crop establishment methods and weed management on productivity of cowpea[*Vigna unguiculata* (L.)Walp.]"** is a record of research work done independently by **Mrs.Ayisha Jezla P.**(2019-11-125) under my guidance and supervision and that it has not been previously formed the basis for the award of any degree, diploma ,associateship or fellowship to her.

Vellanikkara
Date:27-04-2022

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We, the undersigned members of the advisory committee of **Mrs. Ayisha Jezla P.** (2019 -11- 125), a candidate for the degree of **Master of Science in Agriculture**, with major field in Agronomy, agree that this thesis entitled **"Crop establishment methods and weed management on productivity of cowpea[*Vigna unguiculata* (L.) walp.]"** may be submitted by **Mrs. Ayisha Jezla P.**(2019 -11- 125) in partial fulfilment of the requirement for the degree.

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Ayisha Jezla P

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Introduction

1. INTRODUCTION

Pulses are dry seeds of leguminous crops distinguished from leguminous oilseeds by their low fat content. These are most consumed food crop next to cereals in world. The low fat source of protein with high fibre, iron and B vitamins may help to improve diet quality. Pulses are endowed with biological nitrogen fixation and ability to withstand drought with hardy deep root system, which help to increase productivity and achieve sustainability of production.

Cowpea is a warm weather leguminous crop, grown in both tropical and subtropical climate. Better performance under harsh and hardy condition, smothering character, and soil restoring properties are peculiar characters of cowpea. It is grown as sole crop, intercrop, catch crop, cover crop as well as green manure crop for the purpose of green pods, grains and fodder. Cowpea is an essential component of conservation agriculture due to its potential to improve soil condition and ability to act as live mulch. Cowpea grain contains 24-32% protein, 50-60% carbohydrate and 1% fat. Legume protein is rich in lysine and tryptophan, which makes cowpea an excellent complimentary food with rice or wheat.

Weed infestation can lead to decline in yield, intensify pest and disease problem, increase the cost of production and reduce the quality of produce. Though cowpea is a smother, crop competition during the initial phase of growth can adversely affect the crop. So, proper weed control measures during this critical period is important for overall growth and yield of cowpea.

Manual weeding is the most effective and commonly adopted method of weeding, however it is time consuming, laborious and uneconomical in large scale cultivation. Use of herbicides appear to be an alternate option, which is easy, economical, rapid in action, effective and safe, if used properly. Reduced efficiency of pre-emergence herbicides in controlling weeds at later phase of crop growth warrants the use of post-emergence herbicides. Integrating judicious use of herbicides with physical options such as hand weeding can lead to effective weed control.

Broadcasting is the commonly adopted method of planting for cowpea. Line sowing is another method of crop establishment suitable for cowpea. There is an

urgent need to develop weed management strategy for cowpea grown under different crop establishment methods.

Hence, the present study was carried out with the following objective,

- Productivity enhancement of grain cowpea grown under different crop establishment methods through weed management

Review of literature

2. REVIEW OF LITERATURE

Cowpea [*Vigna unguiculata* (L.)Walp.] is cultivated around the world primarily for seed, but also as vegetable, as cover crop, green manure crop and for fodder. Nutritionally, cowpea grain is a dense source of protein (24-32%) and carbohydrate (50-60%) with low fat content (1%). Cowpea protein contain high amount of the amino acid lysine and consumed as natural complimentary food with cereals (Jayathilake *et al*., 2018).

Inadequate weed management practices during critical period of crop weed competition (20-30 DAS) results in drastic yield reduction of cowpea. A good idea of weed spectrum in cowpea field, critical weed competition period, different crop establishment methods, efficiency and economics of different weed control measures are necessary for developing an effective way of weed management for improved production and productivity of cowpea.

2.1 Weed infestation in cowpea

A weed is a plant growing where it is not desired. Based on the morphology, weeds are divided into three, grasses, broad-leaf weeds and sedges. Which compete with the crop for light, nutrients and space, ultimately causing reduction in quality and quantity of the produce (Kavaliauskaite and Bobinas, 2006).

Mathew and Sreenivasan (1998) opined that during summer season dicotyledonous weeds were dominated in cowpea field and in kharif season, sedges and grasses were dominant. Singh and Shwetha, (2005) observed *Echinochloa colonum, Elusine indica, Medicago denticulate, Trianthema monogyna, Commelina benghalensis, Cynodon dactylon* and *Cyperus rotundus* as dominant weed species in black gram field.

According to Tripathi and Singh (2001) *Dactyloctenium aegyptium, Eleusine indica, Cyperus rotundus, Gnaphalium indicum, Sorghum halepense* and *Echinochloa crusgalli* are major weeds in cowpea field. Vivek *et al*. (2008) concluded that black gram field was dominated by *Parthenium hysterophorus, Cynodon dactylon, Digera arvensis, Phyllanthus niruri* and *Echinochloa crusgalli.*

A field experiment conducted in Bangalore showed that major weeds in cowpea field were *Commelina benghalensis, Borrevia hispida, Cyperus rotundus, Cynodon dactylon, Digera arvensis* and *Echinochloa colona* (Hanumanthappa *et al.,* 2012). Puma *et al.* (2013) observed *Dactyloctenium aegyptium, Digitaria sanguinalis, Echinochloa colona, Brachiaria reptans, Elusine indica* and *Cenchrus echinatus* as dominant grassy weeds and *Cleome viscose, Digera arvensis, Portulacastrum, Tribulus terrestris, Crotolaria medicaginea, Corchrus aestuans, Corchrus tridens, Corchrus olitorius, Convolvulus arvensis, Commelina kurzi* and *Molluga distachya* as major dicot weeds in green gram

Komal and Yadav (2015) reported that dominant weed species found in green gram field were *Digera arvensis, Trianthema portulacastrum, Euphorbia hirta, Aristida depressa, Portulaca oleracea, Cleome viscosa, Cyperus rotundus, Elusine verticillata* and *Eragrastris tennela.*

Chaudhari *et al.* (2016) enlisted *Echinochloa crusgalli*, *Cyperus rotundus, Cynodon dactylon, Digitaria sanguinalis, Convolvulus arvensis, Eclipta alba, Amaranthus viridi, Vernonia cinerea, Physalis minima* and *Euphorbia hirta* as major weeds in green gram field in Gujarat.

According to Gupta *et al.* (2016) major weed flora in cowpea field during the experimentation period were *Amaranthus, viridus, Cyperus rotundus, Cyprerus iria, Digera arvensis, Commelina benghalensis* and *Cynodon dactylon.*

2.2 Critical period of weed competition in cowpea

Weeds are one of the crucial constraint for crop production. In cowpea weeds caused 25-76% reduction in yield owing to competition for water, nutrients, light and carbon dioxide (Adigun *et al*., 2014). Weeds may hinder the growth by releasing allelopathic compounds and by providing suitable environment for pest and disease outbreak (Fisichelli *et al*., 2014). Critical period of weed competition is the most appropriate period in crop growth to remove weeds in order to prevent yield and economic loss. Critical period of crop weed competition helps to manage limited resources effectively on weed management.

Weed infestation resulted in 82% reduction of yield and significant increase in pod yield was noted by managing weeds up to 45 DAS (Tripathi and Singh, 2001). Vivek *et al.* (2008) carried out a field study in Meerut to determine critical period of crop weed competition in black gram, and he found that weedy condition during 30-45 DAS resulted in highest yield reduction. Weed free period beyond 45 days had no beneficial result on yield. Osipitan *et al*. (2016) revealed that weed competition is critical during 14 to 40 days of cowpea growth.

Gupta *et al*. (2016) opined that 20-30 DAS is the critical period of weed competition in cowpea and weed infestation during this period produce severe reduction in yield. However, critical period of weed competition is influenced by level of weed infestation, field preparation practices, composition of weed population, soil moisture, fertility level, plant density and type of cultivar (Osipitan *et al*., 2016).

2.3 Effect of weeds on growth and yield

Inadequate weed management of cowpea field resulted in 40-80% yield reduction (Eniola, 2001). Randhawa *et al*. (2002) reported 46.8% seed yield reduction in black gram due to uncontrolled weed competition in field. According to Muhammad *et al*. (2003) interference of weeds caused 82% yield reduction in cowpea. Kumar *et al*. (2004) noted 42% reduction in greengram yield, if weeds are allowed to grow till harvest and he opined that better crop growth and nutrient uptake by greengram in weed free plot is due to reduced competition of crop and weed. Yield reduction of 31.33% was observed in chickpea due to uncontrolled weed infestation (Kachhadia, 2005). Chaudhary *et al*. (2005) found that presence of weeds resulted in reduced yield of 75% in chickpea and higher number of pods per plants (34.5) and grains per pod (1.62) were recorded in weed free plots.

Vivek *et al*. (2008) pointed out that height of blackgram was severely reduced by weed infestation and observed maximum height of plant in weed free plot and minimum in weedy plots. Maximum values of yield parameters like branches/plant, Pods/plant and number of seeds/pod were noted in weed free plots. Sunday and Udensi (2013) mentioned that poorest yield (800 kg/ha) was obtained from unweeded cowpea plot, where percentage reduction of yield was 30.5% compared with weeded plot and high weed dry weight, low ground cover by vines, delayed number of days to

50% flowering were also observed in unweeded plot. Ram (2013) claimed that plant height (62.8 cm), number of branches per plant (11.6), number of nodules per plant (8.99), pods per plant, length of pod (12.07) and seed weight per plant (14.87) found higher under weed free treatment. Biological yield of 3575 kg/ha was recorded in weed free plot which is 79% higher than unweeded plot.

According to Mekonnen *et al*. (2015) weedy condition caused 70.8% yield reduction in cowpea and recorded lowest dry biomass yield. Kumar and Singh (2017) concluded that weed free plot of cowpea showed superiority in grain production over unweeded plot by recording grain weight of 1595.37 kg/ha and higher stover yield. Yadav *et al*. (2019) stated that greengram plot having weeds resulted in lesser production of seed/pod (6.1no), seed yield (265 kg/ha) and straw yield (1085 kg/ha).

2.4. Methods of weed management in cowpea

Weed management is the process of reducing existing weed population in a field, decreasing its interference ability to cause harm and establishment of a barrier for preventing weed infestation in subsequent crops from the current weed species. Singh and Sairam (2016) reported that weed competition in cowpea can be reduced by adopting different methods of weed management. Which includes cultural, physiological, biological and chemical methods.

2.4.1 Hand weeding

Hand weeding is the widely adopted physical method of weed control in cowpea. Fadayomi (1979) pointed out that three times hand weeding within 42 days after emergence of cowpea gave similar yield to weed free plot. Hand weeding is usually difficult due to unavailability and high wage rate of labours, thus making precision of weeding difficult to attain (Lagoke *et al*., 1981). Higuera *et al*. (2001) found that tillage operation reduced weed infestation in cowpea, but there was higher crop injury in tillage compared with non-tillage treatment.

According to Chattha *et al*. (2007) two hand weeding within 30 and 40 days after emergence could control weeds in cowpea effectively but hand weeding during reproductive stage of crop may cause yield reduction due to physical injury to crop and there is a limit to the land area that can be hand weeded.

2.4.2 Chemical weeding

Chemical method of weed control is less expensive and more effective. Which involve the use of herbicides. Gianessi and Reigner (2007) found that use of herbicides reduced 20% of cost of production.

Pre-emergence herbicides are applied before the emergence of crop and weed. They will inhibit seedling establishment by preventing growth of root and shoot. Post-emergence herbicides applied after the emergence of crop and weed. The timing of application of post-emergence herbicides are critical as newly developed weeds are highly susceptible.

Imazethapyr is a systemic herbicide of imidazolinone group. Mode of action is inhibition of acetolactate synthase (ALS), the first common enzyme in the biosynthesis of amino acids valine, leucine and isoleucine and it lead to disruption of protein and DNA synthesis. Selectivity is attributed to rapid detoxification via hydroxylation and glycosylation.

Imazethapyr applied as an early pre-plant, pre-emergent or post-emergence treatment in crop. When applied post-emergence, absorption may occur through both the root and foliage and accumulated in meristematic region. This action helps to retard entire plant including rhizomes and roots. Susceptible weeds stop growing and necrosis begins within 4-8 days. Plant succumb to this herbicide within 7-21 days and provide complete control within 30 days. Applied when the crop has developed at least one fully expanded trifoliate leaf. Grasses, broad-leaf weeds and sedges can be controlled.

Imazamox is a member of the imidazolinone family. A post-emergence herbicide to control grasses, broad leaved weeds and sedges. Uptake of imidazolinone herbicides is primarily through the foliage and roots.The herbicide is translocated to meristematic tissue by the xylem and phloem and inhibits ALS. Protein synthesis and cell division necessary for plant growth are prevented, causing plant to slowly die. Adequate soil moisture provide residual activity on susceptible germinating weeds.

2.4.3. Effect of weed management on weed population, weed control efficiency and weed index

a) Effect of hand weeding on weed population

In a study by Chattha *et al*. (2007) minimum dry biomass of *Echinochloa colona* was recorded when hand weeding done @ 20 and 40 DAS. Singh (2011) revealed that manual weeding @ 20 and 40 DAS recorded low dry matter production of weeds in summer sown blackgram. Two hand weeding at 20 and 40 DAS provided excellent weed control in cowpea with lowest weed dry and weed index (Kujur *et al*., 2015).

Cyperus rotundus, Echinochloa crusgalli, Commelina benghalensis, Phyllanthus niruri and *Digera arvensis* were most common weed species in black gram field which are effectively controlled by two hand weeding @ 20 and 40 DAS(Yadav *et al.,* 2015).

Mekonnen and Dessie (2016) reported that weed dry weight was lower and yield components were higher for cowpea under two hand weeding @ 2 and 5 WAS. Kumar and Singh (2017) reported that hand weeding and intercultural operation @ 20 and 40 DAS resulted in highest weed control efficiency (82.56%) and lowest weed index in cowpea field grown under rainfed condition and very effective to control monocots, dicots and sedges.

According to Yadav *et al*. (2019) lowest weed dry weight, density of *E. colona* and highest weed control efficiency was observed in greengram field, when hand weeding done at 15 and 30 DAS. Highest WCE in black gram field was observed by manual weeding @ 20 and 40 DAS (Rana *et al*., 2019).

b) Effect of chemical weeding on weed population

Chandel and Saxena (2001) revealed efficiency of post-emergence application of imazethapyr at 100 g/ha in controlling weeds of soybean. According to Taylor *et al*. (2002) imazethapyr at 70 g/ha or imazamox @ 36 g/ha could control more than 80% of grasses and broad leaf weeds in soybean field and observed similar levels of reduction in weed biomass. Vyas and Jain (2003) observed that application of pre-mix pendimethalin+imazethapyr at 75 g/ha post-emergence, resulted in higher weed control efficiency and lowest weed biomass.

Kushwah and vyas, (2006) reported that imazamox 60 g/ha or imazethapyr 75 g/ha could effectively reduce population of purple nutsedge. According to Tiwari *et al,* (2006) highest WCE (64.4%) was observed by the application of imazethapyr @ 100g/ha was on par with manual weeding twice at 25 and 45 DAS. An experiment conducted by Kothawade *et al.* (2007) proved that pre-mix of imazamox+imazethapyr is effective in controlling weeds and recorded highest WCE (75.7%) and lowest WI (2.33). Post-emergence application of 0.075 kg/ha imazethapyr @ 20-25 DAS *fb* hand weeding *fb* intercultural operations @ 40-45 DAS resulted in lower weed index and higher weed control efficiency and significantly reduced population of monocot, dicot and sedges (Kumar and Das 2008).

Pre-emergence application of pendimethalin *fb* imazethapyr+imazamox @ 15-20 DAS leads to tremendous growth of crop, which in turn cause smothering effect on late emerged weeds resulted in minimum dry matter of weeds and WCE next to weed free treatment. Spraying of imazethapyr+imazamox caused 63-72% reduction in wooly croton population with little injury (Butler *et al*., 2011). Imazethapyr at 50 g/ha reduced biomass and weed density of broadleaf weed (Meena *et al.*, 2011).

Habimana *et al,* (2013) stated that pre-emergence application of metribuzin *fb* imazethapyr gave lower grasses and broad leaved weed density, weed dry weight and weed population. Younesabadi *et al*. (2013) suggested that pre-mix of pendimethalin at 500 g/ha with imazethapyr at 75 g/ha resulted in higher seed yield of soybean. According to Singh *et al.* (2015) post-emergence application of imazethapyr 75 g/ha at 17 DAS was found to be effective for controlling weeds in green gram field. Sangeetha *et al*, (2013) recorded lower weed biomass and density with hand weeding @ 30 DAS *fb* spraying of imazethapyr @ 100 and 200 g/ha.

Pre-emergence application of imazethapyr @ 75 g/ha along with one hand weeding at 20 DAS is efficient in recording lower weed index and higher weed control efficiency (88.6% (Nagender, 2014). Treatment of imazethapyr+imazamox 60 g/ha at 20 DAS as post-emergence *fb* one hand weeding @ 40 DAS or imazethapyr+imazamox 40 g/ha at 20 DAS and integration with one hand weeding at 40 DAS provided lower weed index and higher weed control efficiency (Komal and Yadav, 2015). According to Yadav *et al*. (2015) highest WCE and lesser dry weight of weeds were observed by the post-emergence application of imazethapyr 0.75 kg

ai/ha *fb* hand weeding @ 40 DAS and was found very effective for reducing density of *Commelina benghalensis.*

Gupta *et al*. (2016) conducted an experiment related with the weed management in cowpea and summarized that minimum weed dry weight of monocot and dicot was recorded under application of imazethapyr+ imazamox @ 20 DAS *fb* imazethapyr @ 20 DAS. Kumar *et al*. (2016) conducted a field experiment to assess efficiency of imazethapyr in greengram. Five different doses of imazethapyr were taken as treatments. Post-emergence application of imazethapyr showed significant reduction of weed population and weed biomass. Effectiveness of herbicide increased up to the dose of 80 g/ha. The highest suppression effect was shown in grassy weeds *fb* sedges *fb* broad leaved weeds. *Cyperus* species was effectively controlled by 100 g/ha of imazethapyr. More than 40 and 60 percentage of WCE and WI was observed at a dose of 100 g/ha of imazethapyr.

Kumar and Singh (2017) reported that hand weeding and intercultural operation @ 20 and 40 DAS resulted in the highest weed control efficiency (82.56%) and lowest weed index in cowpea field grown under rainfed condition and very effective to control monocots, dicots and sedges. Yadav *et al*. (2017) observed that treatment of imazethapyr+imazamox 60 g/ha @ 21 DAS could effectively control goose grass, crowfoot grass, false amaranth and nut sedge, which depend on the stage of weed and time of herbicide application. Spraying of pendimethalin *fb* pre-mix of imazethapyr+imazamox *fb* quizalofop-p-ethyl were more efficient in reducing weed load and resulted in reduction of more than 90% of the grassy weeds. Imazethapyr+imazamox applied @ 60 g/ha at 30 DAS caused reduction of more than 70% of the sedge biomass.

Application of imazethapyr as pre-emergence and post-emergence or imazethapyr+imazamoxas as post-emergence or pre-mix of imazethapyr+pendimethalin resulted in lower weed count and dry weight (Rana *et al*., 2019). Deshkari *et al*, (2019) reported that treatment of imazethapyr+imazamox @100 g/ha followed by one hoeing @ 35 DAS or imazethapyr+imazamox 75 g/ha at 20 DAS or imazethapyr 75 g/ha at 20 DAS *fb* one hoeing at 35 DAS were found to reduce weed dry matter, weed population and weed index.

Yadav *et al*, (2019) reported that pre-emergence application of imazethapyr significantly decresed density of *E. colona* @ 15 DAS. Hand weeding done after taking observation showed good control of *E. colona* @ 45 DAS *fb* hand weeding done @ 15 and 30 DAS *fb* treatment having post-emergence application of imazethapyr. Decreased density of *C. rotundus* was observed in post-emergence application of imazethapyr.

2.4.4 Effect of weed management on crop and yield

Rana and pal (1997) pointed out that hand weeding at 15 and 30 DAS produced higher grain yield of cowpea. Higher grain yield (17.94 q/ha) was obtained under two hand weeding treatment which was on par with spraying of imazamox + imazethapyr (Meena *et al*., 2012). Maximum number of pods and 1000 grain weight in blackgram was obtained by two hand weeding at 25 and 50 DAS (Mansoori *et al*., 2015). Experiment by Pandit *et al*. (2016) revealed that hand weeding at 25 and 45 DAS resulted in the highest grain yield. Hand weeding and intercultural operation at 20 and 40 DAS resulted in significantly higher grain yield (1581 kg/ha), which was on par with the weed free check (1595 kg/ha) in cowpea grown under rainfed condition (Kumar and Singh, 2017).

According to Windley *et al*. (1999), application of imazethapyr at 96 g/ha was safe to mungbean which increased yield by 20.4% over unweeded control and he opined that higher grain yield might be due to efficient weed control, which ultimately improved yield attributes. Tiwari *et al*. (2006) reported that seed yield of soyabean was considerably increased under the application of imazethapyr+imazamox at 2 l/ha.

Higher grain yield, haulm yield, no. of pod per plant, pod weight, no. of grain per pod and 100 grain weight was recorded from soyabean field by the pre-emergence application of mertibuzin *fb* imazethapyr (Habimana *et al.*, 2013). Increased grain yield (292 kg/ha) was obtained by the pre-emergence application of imazethapyr @ 100 g/ha was on par with two hand weeding (Tiwari *et al*., 2006). Higher seed yield (1040 kg/ha) and haulm yield (1548 kg/ha) was recorded by the application of imazethapyr at 75 g/ha with one hand weeding at 20 DAS (Nagender, 2014).

Application of imazethapyr @ 0.075kg/ha *fb* one hand weeding @ 40 DAS increased seed yield by 45%, over the weedy check and the higher plant height,

number of leaves, number of branches, number of pods, pod length was reported from blackgram treated with imazethapyr+imazamox @ 0.05 kg/ha *fb* pendimethalin+ imazethapyr @1 kg/ha (Yadav *et al*, 2015). Singh *et al*. (2015) found that application of imazethapyr 75 g/ha significantly influenced plant height, branches/plant, pod/plant, seed/pod and resulted in higher grain yield and harvest index.

According to Gupta *et al*. (2016) maximum seed yield was recorded under the application of imazethapyr at 20 DAS *fb* imazethapyr+imazamox at 20 DAS. Kumar *et al*. (2016) reported that highest grain yield of green gram was recorded in weed free plot which is on par with imazethapyr treated plot. The increase in plant biomass, root weight, number of seed per plant number of pod per plant contributed for the higher production. Pendimethalin followed imazethapyr+imazamox at 70 g/ha applied at 30 DAS provided soyabean yield similar to weed free control (Yadav *et al*., 2017).

Higher growth and yield parameters of soyabean were observed by Vijay *et al*, (2018) with the treatment of pendimethalin @ 2.5 l/ha which was on par with imazethapyr+imazamox @ 100 g/ha. Spraying of imazethapyr+imazamox 100 g/ha @ 20 DAS followed by one hoeing at 35 DAS or imazethapyr+imazamox 75 g/ha @ 20 DAS or imazethapyr @ 20 DAS *fb* one hoeing@ 35 DAS found to improve yield contributing characters and consequently recorded higher seed yield (Deshkari *et al.*, 2019).

Teli *et al*. (2020) observed higher yield attributes like number of pods/plants and seed yield/plant from plot treated with pendimethalin as pre-emergence *fb* imazethapyr+imazamox as post-emergence, which is statistically on par with weed free treatment. Sasode *et al.* (2020) concluded that post-emergence application of pendimethalin+imazethapyr @ 80 g/ha could increase grain and stover yield by 89% and 33% *fb* post-emergence application of imazethapyr+imzamox 80 g/ha at 20 DAS. Higher values of yield attributes like pods/plant, seed/pod, grain weight/plant and test weight was observed in plots treated with imazethapyr 0.075 kg/ha at 20-25 DAS and one hand weeding *fb* one intercultural operation at 40-45 DAS.

2.4.5 Effect of weed management practices on nutrient uptake by crop

Rana *et al*. (1997) stated that proper weed control caused higher nutrient uptake by crop. Tiwari *et al*. (2006) found higher NPK uptake of soybean when treated with

imazethapyr+ imazamox as post emergence. Higher NPK uptake was obtained from hand weeded control where hand weeding was done 3 and 5 WAS in soyabean and wheat system (Kumar and Das, 2008). Kujur *et al.* (2015) observed the highest NPK uptake in all herbicidal and hand weeded plot compared to unweeded plot. Two hand weeding @ 20 & 40 DAS recorded higher NPK uptake (113.58 kg/ha N, 16.38 kg/ha P and 135.41 kg/ha K) *fb* post- emergence application of imazethapyr @ 75 gm/ha with one hand weeding at 40 DAS.

According to Bhutada and Bhale (2015) higher NPK uptake of chickpea was recorded by the application of pendimethalin followed by hand weeding @ 40 DAS. Shruthi *et al*. (2015) opined that effective weed management practices increased nutrient uptake of green gram. Higher uptake of N (97.16 kg/ha), P (12.56 kg/ha) and K (94.56 kg/ha) were recorded from weed free treatment compared to weedy check of greengram (Komal and Yadav ,2015).

Poornima *et al*. (2018) revealed that hand weeding @ 20 & 40 DAS recorded maximum uptake of nitrogen, phosphorus and potassium by green gram and was on par with the spraying of quizalofop-p ethyl+imazethapyr.

According to Sinchana *et al*. (2020) weed control measures reduced crop weed competition and nutrient removal by weeds resulted in higher NPK uptake of crop by 86.8, 64.7 and 32 percentage respectively over control.

2.5 Method of planting of cowpea

Random scattering of seeds on soil surface is termed as broadcast sowing. It is an easy, quick and cheap method of establishment. Uneven seed germination and heavy weed infestation are main drawbacks. Dibbling or line sowing is the process of placing seeds in holes made at definite depth at fixed spacing which facilitate intercultural practices like weeding, earthing up, and care of individual plants.

2.5.1 Effect of method of planting on weed population

Ichikawa (2000), who found that broadcasted crops are under severe crop-weed competition during early stages of establishment compared with row seeding. Olsen *et al*. (2005) observed lowest weed population in row planting and decreased with increasing sowing rate of crop. Maximum density of weed resulted by the adoption of

broadcast method of sowing followed by line sowing for sesamum grown under irrigated condition (Svathi *et al*., 2005).

Maximum dry weight of weed was noted in broadcasted unweeded plot and lower in ridge planting with herbicide application (Abdullah *et al*.,2008). Ashrafi *et al*. (2009), who concluded that line sowing is superior to broadcasting method of planting for effective weed management practices**.** Cultural management practices like adoption of proper spacing that allow maximum space to be filled in short duration by crop help to reduce weed population and cost of weed management in soyabean field (Mashingaidze *et al*., 2009).

Mahajan and Chauhan (2011) opined that the competitiveness of a crop can be used as an effective tool for suppressing weeds .Biomass of weed was 22% higher in broadcasting than in the row planting of alfalfa and weed population were reduced with increasing sowing rate for all methods of planting (Yazdani *et al.*, 2012). Brennan and Leap (2014) observed delayed emergence and high variability of broadcasted seeds compared with drilled seeds.

Uniform crop establishment in drill seeding resulted in fast growth and helps in smothering weed flora (Kaur *et al*., 2017). Shah *et al*. (2018) noted significance of method of sowing on weed control efficiency and highest WCE was recorded in ridge sowing *fb* bed sowing and line sowing method.

Yadav *et al*. (2019) found that method of planting influence weed density, dry weight of weeds and WCE. Daramola *et al.*(2020) reported that narrow row spacing of 50 cm showed 21-42% reduction in weed density and 20-45% reduction in weed population compared to 75 and 100 cm row spacing. Density of weed species including *Digitaria horizontalis, Panicum maximum, Cynodon dactylon* and *Paspalum scrobiculatum* was higher in wider spacing of 70 cm and 100 cm. According to Saha *et al.* (2021) weed density and weed dry weights are significantly influenced by crop establishment methods and weed control measures. Higher density and dry weight of weeds were recorded in broadcast sowing compared to line sowing.

2.5.2 Effect of method of planting on growth and yield parameters

Plant height of black gram increased when row spacing decreased from 30 to 10 cm (Mishra and Mishra, 1995). According to Mohler *et al*. (2001) crop population and distribution in field influence competition potential of crop with weed. Sowing of green gram in line resulted in higher number of branches, number of leaves, dry matter accumulation, number of pods per plant (17.24) and seeds per pod (8.29). An experiment conducted by Hamid *et al.* (2002) disclosed that LAI, plant dry weight, plant population per plot, branches per plant, pod per plant, seed yield were higher in line sowing than broadcasting.

According to Nimje *et al*. (1996) height of soyabean plant increased from 35.3 cm to 96.5 cm with increasing plant population. Kumar and Thakur (2005) reported sowing crop in line resulted in 10.6% higher yield over broadcasting. Abdullah *et al.* (2008) observed influence of method of planting, herbicide and their interaction on yield of maize crop. Higher yield was obtained for ridge planting with herbicide application while lower for broadcasting and weedy check.

Higher total plant dry weight was recorded in drill sowing method and minimum in broadcasted sowing (Soomro *et al*., 2009). Line sowing in chickpea resulted in higher grain yield, straw yield and protein level (Yadav *et al*., 2010).

According to El Naim *et al.* (2010) increasing plant population increased plant height, seed yield per unit area and decreased number of leaves per plant, LAI, number of pods per plant, 100 seed weight, seed yield per plant and harvest index. Broadcast sowing caused higher biological yield, higher days to maturity and harvest, while higher grain yield and thousand grain weight were recorded in line sowing (Ahmed *et al*., 2011). Choudhary and Suri (2014) opined that suitable sowing methods determines the productivity of crops. Mohammed and Astatkie (2014), who reported that higher grain yield was obtained under narrow row spacing of 40 cm than wider spacing of 60 cm of soyabean.

According to Walkleya and Meleta (2016) maximum height of plant, pod per plant, biomass and yield were noticed in row planting compared to broadcast planting and 20.2% higher yield gained from line sowing. Higher grain and haulm yield was obtained under country plough sowing followed by line sowing and lower yield from

broadcasted chickpea (Mathew *et al*., 2017). Liebert and Ryan (2017) reported that increase in planting rate of soybean decreased weed biomass and increased yield. Seed yield gained by line sown fababean was 22 percentage higher than broadcasted crops.

The geometry of the plant is believed to be an important factor in determining the degree of competition between plants, and maximum performance of crop is achieved when competition is low. Spacing between plants depends on plant type, growing season, variety, and planting system. A plant population that is too low and high has a negative impact on crop yield (Agaji *et al.,* 2018). Maximum yield was obtained from drill seeding followed by line sowing, and 17% reduction was observed in broadcast sowing (Saha *et al* ., 2021).

2.6. Economics

Physical methods of weed control are expensive due to high labour cost (Khan *et al*, 2004). Weed management by using herbicide reduced the cost of production by 20% and could replace 10 labours for weed management. Compared with hand weeding high efficiency of herbicide increased yield of crop by reducing crop weed competition (Gianessi and Reigner, 2007). Higher net return and B:C ratio of 1.68 was recorded by the treatment of imazethapyr 10% at 100 g/ha *fb* imazethapyr at 150 g/ha (Meena *et al,* 2011). Ram (2013) found that among weed management treatments higher gross return and net return was obtained by the treatment of imazethapyr @ 75 and 100 g/ha in soyabean.

Mansoori *et al.* (2015) reported higher net return and B:C ratio with pre-mix application of imazethapyr+imazamox at 50 g/ha followed by imazethapyr+pendimethalin at 1000 g/ha in black gram. Post-emergence application of imazethapyr+imazamox at 0.05 kg/ha and pendimethalin+imazethapyr at1.0 kg/ha resulted in higher net return and B:C ratio (Yadav *et al.,* 2015). Application of pendimethalin 1 kg ai/ha +1 HW at 40 DAS and imazethapy 0.074 kg ai/ha at 20 DAS + HW at 40 DAS realized maximum net return and B:C ratio in forage cowpea (Yadav *et al*,2015).

According to Komal and Yadav (2015) higher net profit (50102/ha) and B:C (3.05) ratio was resulted from weed free treatment and application of pendimethalin *fb*

imazethapyr treatment was next best with respect to return and benefit cost ratio. Imazethapyr @ 40g/ha resulted in higher net return and B:C ratio (3.46) in cowpea (Gupta *et al.*, 2016). Kumar *et al,* (2016) revealed that higher net return was obtained from green gram plot treated with imazethapyr @100 g/ha. According to Singh and Sairam (2016) imazaethapyr @ 35 g /ha + imazamox@ 35 g /ha was the best treatment in terms of net return and B:C ratio. Higher gross and net return and B:C ratio was noted when imazethapyr+imazamox was applied at 80 g/ha, followed by the application of imazethapyr at 80 g/ha (Rana *et al.*, 2019).

Materials and methods

3. MATERIALS AND METHODS

A field experiment entitled "Crop establishment methods and weed management on productivity of cowpea [*Vigna unguiculata* (L.) Walp.]" was undertaken from October-December 2020 at Agronomy Farm, Department of Agronomy, College of Agriculture, Vellanikkara. The details of materials and methods for experimentation are described in this chapter.

3.1 General details

3.1.1 Location

The field experiment was conducted at the Agronomy Farm Department of Agronomy, College of Agriculture, Vellanikkara, Thrissur, Kerala, situated at 10° 31′ N and longitude of 76° 13′ E, at an altitude of 40.3 m above mean sea level (MSL).

3.1.2 Season

The experiment was conducted during rabi season, from October 2020 to December 2020. The crop duration was 70 days.

3.1.3 Climate

The important meteorological parameters during experimental period are presented in Appendix 1

3.1.4 Soil

The soil of the experimental site is sandy loam and acidic in reaction. The properties of the soil before experiment are presented in Table 1.

Table 1. Pre experimental status of soil

Particulars	Value	Method adopted
pH	4.03	pH meter (Jackson, 1958)
EC (µS)	0.63	EC meter (Jackson, 1958)
Organic carbon (%)	1.21	Chromic acid wet digestion method(Walkley and Black ,1934)
Available N (kg/ha)	180	Alkaline permanganate method(Subbaih and Asija, 1956)
Available P_2O_5 (kg/ha)	135	Ascorbic acid reductant method(Bray and Kurtz, 1945)
Available K_2O (kg/ha)	253	Neutral normal ammonium acetate method using flame photometer(Jackson, 1958)

3.2 Details of the experiment

3.2.1 Technical programme

The experiment was laid out in RCBD with three replications during second season of 2020 with 12 treatment combinations .Treatments consisted of six weed management practices and two methods of crop establishments. The herbicides used are given in Table 2.

Design :Factorial RCBD

Treatments : 12

Replications : 3

Plot size : 3.6 m x 3.6 m

Variety : PGCP 6

Spacing : 45 cm x 15 cm

Seed rate : 25 kg/ha (broadcasting) & 40 kg/ha (line sowing)

Table 2. Herbicides used in the experiment

Herbicide	Trade name and formulation	Quantity	Price (Rs/quantity)	Colour code	Dose(g/ha)	Application time
Imazethapyr	Selector 10% SL	250 ml	375	Green	40	Post-emergence, @ 15-20 DAS
Imazethapyr+ imazamox	Odyssey 70 WG	40g	795	Green	40	Post-emergence,@ 15-20 DAS

3.2.2 Treatments

Factor A

Crop establishment methods

1. Broadcasting
2. Line sowing

Factor B

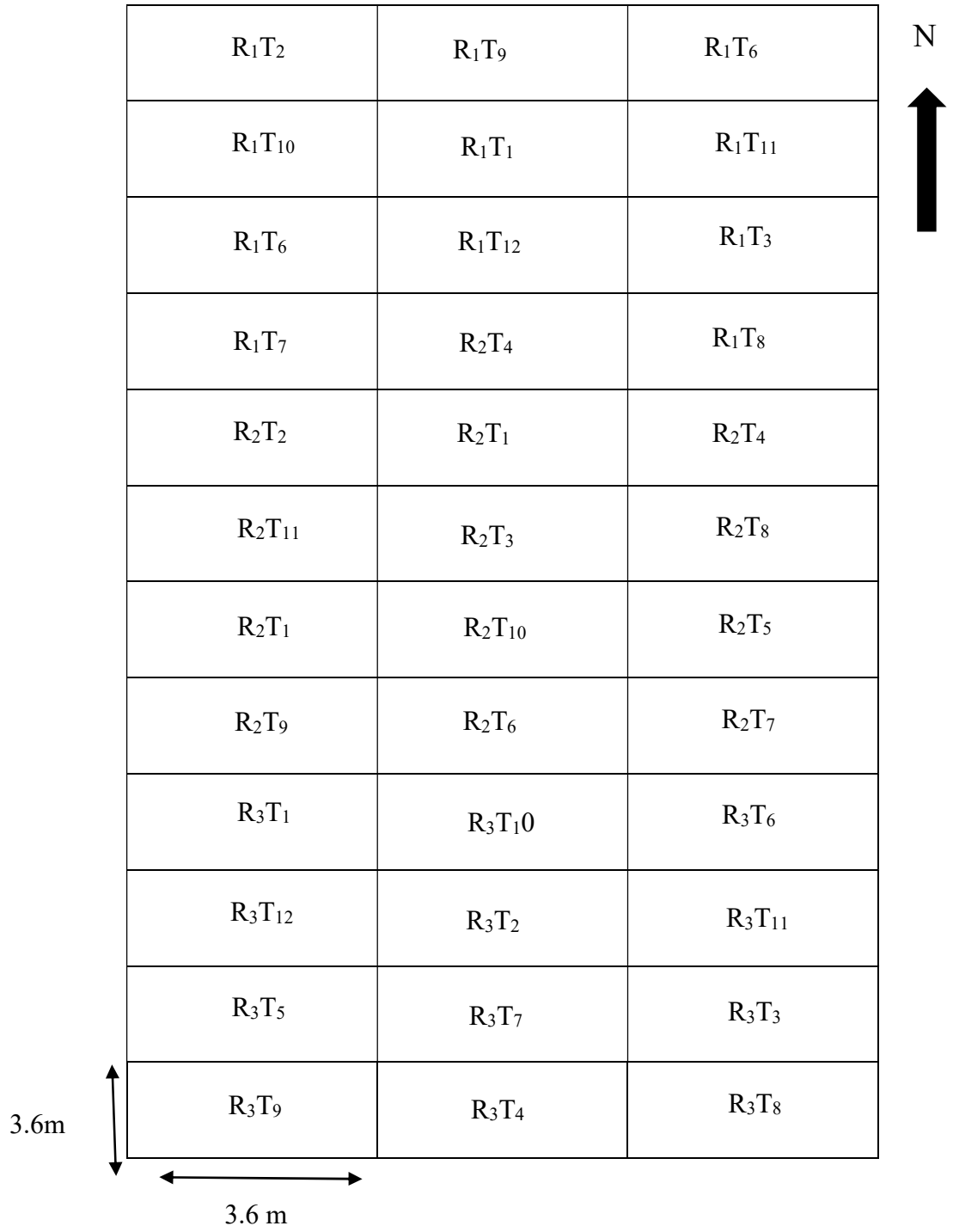
Weed management

1. Hand weeding @ 20 and 40 DAS
2. Imazethapyr +imazamox, 40 g/ha @ 15-20 DAS
3. Imazethapyr +imazamox, 40 g/ha at 15- 20 DAS + Hand weeding @ 40 DAS
4. Imazethapyr, 40 g/ha @ 15- 20 DAS
5. Imazethapyr, 40 g/ha at 15- 20 DAS + Hand weeding @ 40 DAS
6. Unweeded control

Table 3. Treatment combinations

Treatment details	
T_1	Broadcasting+ Hand weeding @ 20 and 40 DAS
T_2	Broadcasting + Pre-mix of Imazethapyr +imazamox, 40 g/ha @ 15-20 DAS
T_3	Broadcasting + Pre-mix of Imazethapyr +imazamox, 40 g/ha @15-20 DAS + Hand weeding @ 40 DAS
T_4	Broadcasting+ Imazethapyr, 40 g/ha @ 15- 20 DAS
T_5	Broadcasting+ Imazethapyr, 40 g/ha @15- 20 DAS + Hand weeding @ 40 DAS
T_6	Broadcasting + Unweeded control
T_7	Line sowing + Hand weeding @ 20 and 40 DAS
T_8	Line sowing + Pre-mix of Imazethapyr +imazamox, 40 g/ha @ 15-20 DAS
T_9	Line sowing + Imazethapyr +imazamox, 40 g/ha @ 15-20 DAS+ Hand weeding @ 15-20 DAS
T_{10}	Line sowing + Imazethapyr, 40 g/ha @ 15- 20 DAS
T_{11}	Line sowing + Imazethapyr, 40 g/ha @ 15- 20 DAS + Hand weeding @ 40 DAS
T_{12}	Line sowing + Unweeded control

Layout



R_1T_2	R_1T_9	R_1T_6
R_1T_{10}	R_1T_1	R_1T_{11}
R_1T_6	R_1T_{12}	R_1T_3
R_1T_7	R_2T_4	R_1T_8
R_2T_2	R_2T_1	R_2T_4
R_2T_{11}	R_2T_3	R_2T_8
R_2T_1	R_2T_{10}	R_2T_5
R_2T_9	R_2T_6	R_2T_7
R_3T_1	R_3T_10	R_3T_6
R_3T_{12}	R_3T_2	R_3T_{11}
R_3T_5	R_3T_7	R_3T_3
R_3T_9	R_3T_4	R_3T_8

Figure 3.1 Lay out of the experiment

3.3 Field operations

3.3.1 Land preparation

The experimental field was ploughed with tractor .The weeds and stubbles of previous crops were removed and field lay out was done. Beds of size 3.6 m X 3.6 m were prepared for each treatment.

3.3.2 Application of Lime, FYM and fertilizers

Lime was applied @ 250 kg/ha, before planting to reduce acidic nature of soil. FYM was applied @ 20 t/ha .Urea, factomphos and murate of potash were given to supply 20:30:30 kg N, P_2O_5 and K_2O per hectare. Half dose of nitrogen and full doses of phosphorus and potassium were applied basally and the remaining nitrogen was given in two equal splits at 15^{th} and 30 DAS.

3.3.3 Seed rate and sowing

Short duration cowpea variety PGCP-6 (Pant lobia 3) released from Pantnagar Agricultural university were used as test crop. Broadcasting and line sowing were done in respective plots at 25 Kg/ha and 40 kg/ha respectively. Line sowing was done at a spacing of 30 cm X 15 cm .Thinning and gap filling was done five days after sowing to maintain plant population.

3.3.4 Plant protection

Plant protection measures were given as and when required. Aphids were managed by imidacloprid at the rate of 2 ml/L during early flowering stage. Pod borers were noticed in the field and controlled by the application of chlorantraniliprole at the rate of 3 ml/10L.

3.3.5 Herbicide application

Application of imazethapyr 10% SL @ 40 g/ha was done in T_4, T_5, T_{10} and T_{11} treatments at 15 DAS. Pre-mix of imazethapyr + imazamox 70 WG @ 40 g/ha was sprayed at 15 DAS in T_2, T_3, T_8 and T_9 treatments. Herbicide was applied during early morning with a knapsack sprayer fitted with flood jet nozzle. 500 L water per hectare taken as spray volume.

3.3.6 Hand weeding

Hand weeding was done at 40 DAS along with herbicide application in T_3, T_5, T_9 and T_{11} treatments. T_1 and T_7 were maintained weed free where hand weeding was done at 20 and 40 DAS.

3.3.7 Irrigation

Irrigate the field at 3 days interval for the first two weeks after planting. The subsequent irrigation was given at flowering and pod initiation stages.

3.3.8 Harvesting

First harvest of crop was done on 4th December, when colour of pod changed from green to yellow. Subsequent picking was carried out on12th December and 24th December. Seeds are separated by manual threshing.

Plate 1. Field preparation

Plate 2. Line sowing

Plate 3. Crops in line sown plot one week after sowing

Plate 4. Field view at 2 week after sowing

Plate 5. Herbicidal application at 20 DAS

Plate 6. Field view at 6 week after sowing

Plate 7. Field at first harvest

Plate 8. Field at second harvest

Plate 9. Field at third harvest

3.4. Observations recorded

3.4.1 Biometric observations

a) Plant height

Five plants were selected randomly from each plot and height of plant was measured from ground level to the tip of plant. Observations were noted at 30 DAS, and 60 DAS.

b) Number of leaves per plant

Number of leaves from randomly selected plants in each plot were counted at 30 DAS and 60 DAS and mean was calculated.

c) Number of branches per plant

Number of branches from main stem of the selected plants were noted at 30 DAS and 60 DAS. Average number of branches from each plant was worked out.

d) Leaf area index

Linear method is adopted for estimating leaf area index of trifoliate leaves at 20, 40 and 60 DAS.

$$LAI = \frac{\text{Leaf area of plant in cm}^2}{\text{Ground area occupied by plant in cm}^2}$$

Leaf area = L X B X K X n

L = Length of leaf in cm

B = Breadth of leaf in cm

K = 0.631 (Montgomery, 1911)

n = Number of leaves

e) Total dry matter production at harvest

Five plants were uprooted from each plot and air dried for 24 hour. Plants were kept in brown paper cover and dried in hot air oven to constant weight. Total dry matter production of plants were computed and expressed in kg/ha.

3.4.2 Yield and yield parameters

a) Number of pods per plant

Yellow coloured pods from randomly selected plants were counted after each harvest and average was worked out to record pods per plant.

b) Number of seeds per pod

Number of seeds from five mature pods of tagged plants in each plot was counted and mean was worked out to record average number of seeds per pod.

c) 100 seed weight

Weight of hundred healthy seeds from tagged plants of each plots were selected and weight was recorded.

d) Pod weight

Weight of matured harvested pods from tagged plants were recorded and mean fresh weight was worked out.

e) Days to 50 % flowering

Number of days taken for 50% flowering was noted for each plot

f) Grain yield

Seed yield from each plot was noted after each harvest and the total grain yield was expressed in kg/ha

3.4.3 Observations on weeds

a) Weed count

Weed count was noted using a quadrat of 50 cm X 50 cm (0.25 m^2) at 30 DAS, 60 DAS and at harvest. Weeds within the quadrat were grouped in to broad leaved weeds, grasses and sedges and counted.

b) Weed dry matter production

Weeds from each quadrat were uprooted and air dried after removing soil particles. Dry weight of weeds were recorded after oven drying at 80°C and expressed in g/m^2.

c) Weed Control Efficiency (%)

WCE was calculated by using formula given by Mani and Gautham (1973) @ 30, 60 DAS and at harvest.

$$WCE = \frac{\text{DMP in unweeded plot- DMP in treated plot}}{\text{DMP in unweeded plot}} X100$$

DMP- Dry matter production of weed

d) Weed Index

Weed index was work out by formula suggested by Gill and Kumar (1969) and expressed in percentage.

$$WI = \frac{\text{Grain yield from hand weeded plot- Grain yield from treated plot}}{\text{Grain yield from hand weeded plot}} X\ 100$$

3.5. Plant analysis

a) N, P_2O_5, K_2O uptake at harvest

N, P_2O_5, K_2O of plants from each treatment was estimated. Samples were dried till constant weight, then powdered and used for analysis

Table 4. Methods for plant analysis

Nutrients	Method
Nitrogen	Micro kjeldahl method (Jackson, 1958)
Phosphorus	Diacid extract method using spectrophotometer (Jackson, 1958)
Potassium	Diacid extract method using flame photometer (Jackson, 1958)

3.6 Soil characteristics

Soil sample from different parts of experimental field was collected and pooled for pre-experimental analysis. Soil sample from each plot were taken separately for post analysis.

a) pH

pH meter was used for measuring pH. Soil and water were taken in 1:2.5 ratio and stirred well. Electrode was dipped in soil water suspension and pH was recorded.

b) EC

EC was measured by electrical conductivity meter. Soil water suspension was prepared by mixing soil and water in 1:2.5 ratio and electrode of EC meter was immersed and reading was noted.

c) Available N, P and K

Alkaline potassium permanganate method by Subbaiah and Asija (1956) was used to estimate available N. Ascorbic acid reductant method (Watanabe and Olsen, 1965) and procedure suggested by Jackson (1958) were adopted for the determination of P and K respectively.

d) Organic carbon

Walkley and Black (1934) method was used for organic carbon estimation and it was expressed in percentage.

3.7. Economics of cultivation

a) Net income

Net income was calculated using formula

Net income (Rs/ha) = Gross income – Cost of cultivation

b) B:C ratio

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

3.8 Statistical analysis

Statistical analysis of field experiment data was carried out with the help of online statistical tool GRAPES (General R based Analysis Platform Empowered by Statistics). Square root transformation $\sqrt{(x + 0.5)}$ was applied wherever data showed wide variations.

Results

4. RESULTS

The field experiment on "Crop establishment methods and weed management on productivity of cowpea [*Vigna unguiculata* (L.) Walp.]" was conducted from October to December 2020 at the Department of Agronomy, College of Agriculture, Vellanikkara. The objective of the experiment was productivity enhancement of grain cowpea grown under different crop establishment methods through weed management. The result obtained after statistical analysis of observed data are presented in this chapter.

4.1 Observations on weeds

4.1.1 Weed flora

Broad leaved weeds, grasses and sedges were observed in the field. Among broad leaved weeds *Phyllanthus amara, Mimosa pudica, Mitracarpus hirtus, Euphorbia hirta, Scoparia dulcis, Ageratum conyzoides, Cleome burmannii* and *Mollugo sp.* were dominant. *Digitaria ciliaris*, *Echinochloa colona*, *Cynodon dactylon* and *Oryza sativa* were major ones among grassy weeds. Sedges count was very low in the field. *Cyperus iria* was the only sedge observed in plots.

a) Broad leaf weeds

Effect of various crop establishment methods and weed management practices on broad leaf weeds at 30 and 60 DAS are given in Table 5 and 6.

Density of broad leaf weeds were significantly influenced by method of establishment at 30 DAS. Significantly higher density of broad leaf weeds were observed in broadcast sowing (8.11 no./m^2) compared with line sowing (5.50 no./m^2). At 60 DAS, broad leaf weed count was not significantly influenced by method of planting.

Broad leaf weed density was significantly influenced by weed management practices both at 30 and 60 DAS. At 30 DAS Weedy check recorded significantly higher density of 20.66 no./m^2 followed by imazethapyr, 40 g/ha @ 15-20 DAS was on par with imazethapyr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS, imazethapyr +

imazamox, 40 g/ha @ 15- 20 DAS, imazethapyr + imazamox, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS, hand weeding @ 20 and 40 DAS. At 60 DAS significantly higher BLW density was recorded in weedy check (8.50 no./ m^2) followed by imazethapyr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS which was on par with imazethapyr + imazamox, 40 g/ha @ 15- 20 DAS. Significantly lower BLW density was recorded in hand weeded treatment.

Interaction effect was non significant with respect to BLW density both at 30 and 60 DAS.

b) Grasses

Data on effect of crop establishment methods and weed management practices on grasses at 30 and 60 DAS are given in Table 5 and 6.

Density of grasses were significantly influenced by method of planting only at 30 DAS. The lowest grass density of 2.72 no./m^2 was observed in line sowing compared to broadcasting (5.22 no./m^2).

All weed management practices found to reduce grassy weeds both at 30 and 60 DAS. Higher density of 10.67 no./m^2 and 5.02 no./m^2 was observed in weedy check at 30 and 60 DAS, respectively. At 30 DAS, hand weeding twice recorded lower density of grassy weeds (2.00 no./m^2) which was statistically comparable with all chemical weed control practices. At 60 DAS significantly lower density of grassy weeds were observed in imazethapyr + imazamox, 40 g/ha @ 15- 20 DAS *fb* HW @ 40 DAS was on par with hand weeding @ 20 and 40 DAS, imazethapyr +imazamox, 40 g/ha @ 15-20 DAS, imazethapyr, 40 g/ha @ 15- 20 DAS and imazethapyr, 40 g/ha @15- 20 DAS + hand weeding @ 40 DAS.

Interaction effect was non significant with respect to grassy weed density at 30 and 60 DAS.

c) Sedges

Data on effect of crop establishment methods and weed management practices on sedges at 30 and 60 DAS are given in Table 5 and 6.

At 30 DAS sedges count was influenced by crop establishment methods. Higher population of sedges were observed in broadcast sowing (0.83 no./m^2). However, weed management treatments did not have any significant impact on density of sedges at 60 DAS.

Interaction effect was non significant with respect to sedges count both at 30 and 60 DAS.

d) Total weed count

Effects of treatment on total weed count are given in Table 7 and 7a.

Total weed count was significantly influenced by different methods of planting of cowpea at 30 DAS. Line sowing recorded the lowest total weed count at 30 DAS (8.66 no./ m^2). Significantly higher total weed count was observed in broadcasted plot (14.18). However at 60 DAS method of planting had no significant effect on total weed count.

Total weed count at 30 and 60 DAS was significantly influenced by weed management practices. At 30 DAS hand weeding twice recorded the lowest total weed count and significantly higher total weed count was recorded in unweeded plot (34.00 no./m^2). At 60 DAS, hand weeding twice and imazethapyr + imazamox, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS recorded significantly lower total weed count. The highest total weed count was observed in unweeded control (13.66 no./m^2) followed by imazethapyr, 40 g/ha @ 15-20 + HW @ 40 DAS.

Interaction effect was significant with respect to total weed count at 30 DAS. Significantly lower total weed count was noted in line sown plot treated with imazethapyr, 40 g/ha @ 15- 20 DAS. The highest total weed count was recorded in broadcasted weedy check.

4.1.2 Weed dry weight

Data on weed dry weight as influenced by different treatments are given in Table 8 and 8a.

Weed dry weight was significantly influenced by crop establishment methods at 30 and 60 DAS. Lower dry weight was observed in line sowing (3.50 and 4.66 g/m^2) compared with broadcast sowing (5.09 and 4.91 g/m^2).

Weed dry weight at 30 and 60 DAS was significantly influenced by weed management practices. At 30 DAS, the highest dry weight of weeds were recorded from unweeded control and lesser weed dry weight was observed in hand weeding @ 20 and 40 DAS (1.34 g/m^2). At 60 DAS, the lowest weed dry weight was noted in hand weeding @ 20 and 40 DAS (2.01 g/m^2), which was statistically comparable with imazethapyr, 40 g/ha @ 15- 20 DAS and imazethapyr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS and higher weed dry weight recorded in unweeded control (15.08 g/m^2) followed by imazethapyr + imazamox, 40 g/ha @ 15-20 DAS.

Interaction effect was significant with respect to total weed dry weight at 30 and 60 DAS. At 30 DAS, hand weeding done in line sown plot recorded significantly lower weed dry weight (1.31 g/m^2), which was statistically on par with application of pre-mix of imazethapyr + imazamox, 40 g/ha @ 15- 20 DAS *fb* HW @ 40 DAS in line sown plot. Significantly higher weed dry weight was noted in broadcasted weedy check. At 60 DAS lower weed dry weight was recorded in line sown plot treated with imazethapyr, 40 g/ha @ 15- 20 DAS (1.88 g/m^2) which was statistically on par with broadcasted plot with treatment hand weeding @ 20 and 40 DAS and the highest was noted in broadcasted weedy check (15.66 g/m^2) followed by line sown weedy check.

4.1.3 Weed control efficiency

Data on WCE as influenced by different treatments are given in Table 9m 9a.

WCE was influenced by crop establishment methods. At 30 and 60 DAS, line sowing recorded higher weed control efficiency of 75.49 and 70.21 percentage, compared to broadcasting, which recorded 64.41 and 68.61 percentage at 30 and 60 DAS, respectively.

Weed management practices also influenced the weed control efficiency. At 30 DAS, higher WCE was noted in hand weeding @ 20 and 40 DAS (90.34 %) followed by imazethapyr + imazamox, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS (84.7%), which was on par with imazethapyr, 40 g/ha @ 15- 20 DAS (81.73%). Unweeded plot

recorded lower WCE of 9.66 %. At 60 DAS also, hand weeding twice recorded higher WCE (87.38%) which was on par with imazethapyr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS and imazethapyr, 40 g/ha @ 15- 20 DAS.

WCE at 30 and 60 DAS was influenced by interaction effect. The line sown plot with treatment of hand weeding twice recorded higher WCE of 90.49% which was comparable with broadcasted field with treatment of hand weeding twice (90.20 %) and line sown plot applied with imazethapyr + imazamox, 40 g/ha @ 15- 20 DAS *fb* HW @ 40 DAS (89.27%), at 30 DAS. At 60 DAS higher WCE was noted in treatment combination of line sowing with application of imazethapyr, 40 g/ha @ 15-20 DAS (87.97%), which was on par with broadcasted field where two hand weeding were conducted, line sown plot with treatment of hand weeding twice and broadcasted plot sprayed with imazethapyr, 40 g/ha @ 15- 20 DAS *fb* hand weeding @ 40 DAS.

4.1.4 Weed index

Effect of treatments on WI are presented in Table 9 and 9a.

Crop establishment methods have effect on weed index. Line sowing recorded lower WI of 22.04 % compared with broadcasting having WI of 24.63 %.

Among weed control treatments imazethapyr + imazamox, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS registered the lowest WI.

WI was influenced by interaction effects. The lowest WI was recorded in line sown plot applied with imazethapyr + imazamox, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS. Higher WI was recorded in weedy check.

Table 5. Effect of crop establishment methods and weed management practices on BLW, grasses and sedges at 30 DAS

Treatments	BLW (no./ m^2)	Grasses (no./ m^2)	Sedges (no./m^2)
Crop establishment methods			
Broadcasting	*2.78 (8.11)	2.28 (5.22)	1.07 (0.83)
Line sowing	2.20 (5.50)	1.64 (2.72)	0.88 (0.44)
SE (m)	0.07	0.85	0.06
CD (0.05)	0.22	0.25	0.17
Weed management practices			
HW @ 20 and 40 DAS	2.06 (3.83)	1.51 (2.00)	0.71 (0.00)
Imzr+imzx, 40 g/ha @15-20 DAS	1.99 (3.83)	1.72 (2.50)	0.88 (0.33)
Imzr+imzx, 40g/ha @15-25 DAS *fb* HW@ 40 DAS	1.96 (3.50)	1.80 (2.83)	0.85 (0.33)
Imzr, 40 g/ha @ 15- 20 DAS	2.27 (4.83)	1.92 (3.50)	0.85 (0.33)
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	2.15 (4.16)	1.53 (2.33)	0.79 (0.17)
Unweeded control	4.58 (20.66)	3.28 (10.67)	1.77 (2.67)
SE (m)	0.13	0.15	0.10
CD (0.05)	0.38	0.43	0.30

*√(x + 0.5) –Transformed values, original values in parenthesis

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

Table 6. Effect of crop establishment methods and weed management practices on BLW, grasses and sedges at 60 DAS

Treatments	Weed count at 60 DAS		
	BLW (no./ m^2)	**Grasses (no./ m^2)**	**Sedges (no./m^2)**
Crop establishment methods			
Broadcasting	*2.08 (4.11)	1.71 (2.33)	0.82 (0.22)
Line sowing	2.13 (4.39)	1.61 (2.44)	0.79 (0.17)
SE (m)			
CD (0.05)	NS	NS	NS
Weed management practices			
HW @ 20 and 40 DAS	1.56 (2.01)	1.32 (1.33)	0.71 (0.00)
Imzr+imzx, 40 g/ha @15-20 DAS	2.17 (4.31)	1.45 (1.83)	0.71 (0.00)
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	1.65 (2.37)	1.17 (1.00)	0.79 (0.16)
Imzr, 40 g/ha @ 15- 20 DAS	2.07 (4.00)	1.68 (2.67)	0.79 (0.16)
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	2.19 (4.33)	1.71 (2.50)	1.05 (0.66)
Unweeded control	2.99 (8.50)	2.34 (5.02)	0.79 (0.16)
SE (m)	0.15	0.17	
CD (0.05)	0.43	0.51	NS

*$\sqrt{(x + 0.5)}$ –Transformed values, original values in parenthesis

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

Table 7. Effect of crop establishment methods and weed management practice on

Treatments	Total weed count (no./m^2)	
	30 DAS	**60 DAS**
Crop establishment methods		
Broad casting	*3.65 (14.18)	2.61 (6.72)
Line sowing	2.74 (8.66)	2.65 (6.94)
SE (m)	0.03	
CD (0.05)	0.09	NS
Weed management practices		
HW @ 20 and 40 DAS	2.48 (5.83)	1.95 (3.30)
Imzr+imzx, 40 g/ha @15-20 DAS	2.64 (6.75)	2.61 (6.30)
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	2.63 (6.63)	1.95 (3.30)
Imzr, 40 g/ha @ 15- 20 DAS	2.92 (8.66)	2.70 (6.80)
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	2.64 (6.60)	2.88 (7.50)
Unweeded control	5.86 (34.00)	3.76 (13.66)
SE (m)	0.08	0.05
CD (0.05)	0.23	0.14

total weed count

*√(x + 0.5) –Transformed values, original values in parenthesis

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

Table 7a. nteraction effect of crop establishment methods and weedmanagement practices on total weed count

Treatments	Total weed count (no./m^2)
	30 DAS
Broadcasting	
HW @ 20 and 40 DAS	*2.88 (7.66)
Imzr+imzx, 40 g/ha @15-20 DAS	3.07 (9.00)
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	3.07 (9.00)
Imzr, 40 g/ha @ 15- 20 DAS	3.71 (13.33)
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	3.08 (9.02)
Unweeded control	6.12 (37.00)
Line sowing	
HW @ 20 and 40 DAS	2.11 (4.01)
Imzr+imzx, 40 g/ha @15-20 DAS	2.20 (4.33)
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	2.20 (4.33)
Imzr, 40 g/ha @ 15- 20 DAS	2.11 (3.96)
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	2.23 (4.49)
Unweeded control	5.61 (31.00)
SE (m)	0.08
CD (0.05)	0.23

*$\sqrt{(x + 0.5)}$ –Transformed values, original values in parenthesis

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

Table 8. Effect of crop establishment methods and weed management practices on weed dry weight

Treatments	Weed dry weight (g/m^2)	
	30 DAS	**60 DAS**
Crop establishment methods		
Broadcasting	*2.23 (5.09)	2.16 (4.91)
Line sowing	1.86 (3.50)	2.12 (4.66)
SE (m)	0.03	0.09
CD (0.05)	0.10	0.02
Weed management practices		
HW @ 20 and 40 DAS	1.34 (1.34)	1.58 (2.01)
Imzr+imzx, 40 g/ha @15-20 DAS	1.97 (3.47)	2.26 (4.60)
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	1.63 (2.19)	1.88 (3.04)
Imzr, 40 g/ha @ 15- 20 DAS	1.75 (2.60)	1.59 (2.03)
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	1.90 (3.20)	1.59 (2.02)
Unweeded control	3.66 (12.97)	3.94 (15.08)
SE (m)	0.06	0.09
CD (0.05)	0.17	0.02

*$\sqrt{(x + 0.5)}$ –Transformed values, original values in parenthesis

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

Table 8a. Interaction effect of crop establishment methods and weed management practices on total weed dry weight

Treatments	Weed dry weight (g/m^2)	
	30 DAS	60 DAS
Broadcasting		
HW @ 20 and 40 DAS	*1.35 (1.36)	1.58 (2.01)
Imzr+imzx, 40 g/ha @15-20 DAS	2.18 (4.26)	2.26 (4.63)
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	1.83 (2.85)	1.88 (3.03)
Imzr, 40 g/ha @ 15- 20 DAS	1.94 (3.25)	1.63 (2.17)
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	2.22 (4.43)	1.59 (2.02)
Unweeded control	3.85 (14.38)	4.02 (15.66)
Line sowing		
HW @ 20 and 40 DAS	1.34 (1.31)	1.58 (2.01)
Imzr+imzx, 40 g/ha @15-20 DAS	1.77 (2.70)	2.25 (4.57)
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	1.42 (1.53)	1.88 (3.05)
Imzr, 40 g/ha @ 15- 20 DAS	1.57 (1.96)	1.54 (1.88)
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	1.57 (1.97)	1.59 (2.03)
Unweeded control	3.47 (11.57)	3.87 (14.48)
SE (m)	0.08	0.01
CD (0.05)	0.24	0.04

*$\sqrt{(x + 0.5)}$ –Transformed values, original values in parenthesis

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

Table 9. Effect of crop establishment methods and weed management practices on weed control efficiency and weed index

Treatments	Weed control efficiency (%)		Weed index (%)
	30 DAS	60 DAS	
Crop establishment methods			
Broadcasting	64.41	68.61	24.63
Line sowing	75.49	70.21	22.04
Weed management practices			
HW @ 20 and 40 DAS	90.34	87.38	-
Imzr+imzx, 40 g/ha @15-20 DAS	75.76	70.55	24.83
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	84.70	80.61	7.81
Imzr, 40 g/ha @ 15- 20 DAS	81.73	87.02	23.97
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	77.50	87.07	11.56
Unweeded control	-	-	70.38

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

Table 9a. Interaction effect of crop establishment methods and weed management practices on weed control efficiency and weed index

Treatments	Weed control efficiency (%)		Weed index
	30 DAS	60 DAS	
Broadcasting			
HW @ 20 and 40 DAS	90.20	87.51	2.94
Imzr+imzx, 40 g/ha @15-20 DAS	70.14	70.26	25.81
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	80.13	80.71	9.35
Imzr, 40 g/ha @ 15- 20 DAS	77.21	86.06	25.35
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	68.81	87.12	13.87
Unweeded control	0.000	0.00	70.47
Line sowing			
HW @ 20 and 40 DAS	90.49	87.16	-
Imzr+imzx, 40 g/ha @15-20 DAS	81.38	70.84	23.85
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	89.27	80.52	6.26
Imzr, 40 g/ha @ 15- 20 DAS	86.26	87.97	22.59
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	86.19	87.03	9.24
Unweeded control	-	-	70.29

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

4.2 Biometric observations

4.2.1 Plant height

Observations on plant height at 30 and 60 DAS are given in Table 10.

Crop establishment methods significantly influenced the plant height at 30 and 60 DAS. Significantly higher plant height of 73.10 cm and 139.24 cm, respectively was noted in line sowing, at 30 and 60 DAS as against 68.30 cm and 120.23 cm of broadcasted crop.

Weed management practices significantly influenced height of plant at 30 DAS. However at 60 DAS height of plant was not significantly influenced by weed management practices. At 30 DAS significantly higher plant height was observed in imazethapyr + imazamox, 40 g/ha @ 15- 25 DAS + HW @ 40 DAS (79.53 cm), which was on par with imazethapyr + imazamox, 40 g/ha @ 15-20 DAS (76.98 cm). Significantly lower plant height was observed in unweeded control.

Interaction effect was non significant with respect to plant height at 30 and 60 DAS.

4.2.2 Number of branches per plant

Observations on number of branches at 30 and 60 DAS are presented in Table 11.

Crop establishment methods had significant effect on number of branches per plant at both stages of observation. At 30 and 60 DAS, significantly higher number of branches (3.46, 8.34) were observed in broadcast method of sowing compared to line sowing.

However, weed management practices and interaction effect of crop establishment methods and weed management practices was non significant with respect to the number of branches at 30 and 60 DAS.

4.2.3 Number of leaves per plant

Observations recorded on number of leaves per plant as influenced by various treatments are given in Table 12.

Method of planting had significant effect on the number of leaves at 30 DAS, but had no significant impact at 60 DAS. At 30 DAS, line sowing recorded significantly higher number of leaves per plant (20.44 cm) compared to broadcasting.

At 30 and 60 DAS, number of leaves were not significantly influenced by main effect of weed management practices and interaction effect of crop establishment methods and weed management practices.

4.2.4 LAI

Data on the effect of treatments on LAI is furnished in Table 13.

Crop establishment methods was significantly influenced leaf area index at 20, 40 and 60 DAS. Higher LAI of 2.37, 6.09 and 7.74 respectively was recorded at 20, 40 and 60 DAS in broadcasted field compared with 1.42, 3.55 and 4.50 in line sown plot.

Weed control measures had significant impact on LAI both at 40 and 60 DAS. At 40 DAS, imazethapyr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS recorded significantly higher LAI of 5.13, was on par with imazethapyr, 40 g/ha @ 15- 20 DAS, imazethapyr+imazamox, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS, imazethapyr+imazamox, 40 g/ha @ 15- 20 DAS and hand weeding twice. Significantly lower LAI was noted in unweeded plot (4.34). At 60 DAS, imazethapyr, 40 g/ha @ 15- 20 DAS registered significantly higher LAI which was on par with imazethapyr + imazamox, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS, imazethapyr+imazamox, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS, imazethapyr+imazamox, 40 g/ha @ 15- 20 DAS and imazethapyr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS.

Interaction effect was non significant with respect to LAI at all three stages of observation.

4.2.5 Total dry matter production at harvest

Data on the effect of treatments on dry matter production is given in Table 13.

DMP was significantly not influenced by crop establishment methods. Significantly higher DMP of 5084.68 kg/ha was noted in imazethapyr, 40 g/ha @ 15-20 DAS + HW @ 40 DAS. Unweeded treatment recorded the lowest DMP of 3399.5 kg/ha.

Interaction effect of treatments was non significant with respect to DMP.

4.3 Observations on yield Parameters

4.3.1 Days to 50 % flowering

Observations on days to 50 % flowering are given in Table 14.

Days to 50% flowering was significantly influenced by crop establishment methods. Broadcast sowing took significantly higher number of days (33.17) for 50% flowering of cowpea compared to line sowing (31.67 days).

Weed management practices and interaction between crop establishment methods and weed management practices was not significantly influenced with respect to days to 50% flowering of crop.

4.3.2 100 grain weight

Effect of treatments on 100 grain weight are presented in Table 14 and Table 14a.

No significant influence was produced by crop establishment methods on 100 grain weight.

The weed management practices had a favourable impact on 100 grain weight. Imazethapyr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS treatment produced significantly higher 100 grain weight (11.57 g) which was statistically comparable with imazethapyr, 40 g/ha @ 15- 20 DAS (11.50 g). Significantly lower 100 grain weight was recorded in unweeded control which was on par with imazethapyr + imazamox, 40 g/ha @ 15- 20 DAS.

Interaction of crop establishment methods and weed control measures was significant with respect to 100 grain weight. The highest 100 grain weight was observed in line sown plot treated with imazethapyr, 40 g/ha @ 15- 20 DAS (11.79 g) was on par with line sown plot applied with imazethapyr, 40 g/ha @ 15- 20 DAS *fb* HW @ 40 DAS. Significantly lower 100 grain weight was noted in broadcast sowing where hand weeding carried out twice.

4.3.3 Number of pods per plant

Data on effect of treatments on number of pod per plant are presented in Table 15 and Table 15a.

Number of pods per plant was not significantly influenced by method of planting. However number of pods per plant was significantly influenced by various weed management practices. The results on number of pods per plant revealed that significantly higher number of pods per plant recorded in imazethapyr + imazamox, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS (42.16), which was on par with hand weeding @ 20 and 40 DAS (41.66). Significantly lower number of pods (31.5) were recorded in unweeded plot.

Interaction effect was significantly influenced number of pods per plant. Line sown plot applied with pre-mix of imazethapyr + imazamox, 40 g/ha @ 15-20 DAS *fb* HW @ 15-20 DAS (42.33) recorded the highest number of pods per plant. Unweeded line sown plot registered significantly lower number of pods per plant.

4.3.4 Number of seeds per pod

Number of seeds per pod as influenced by different treatments are presented in Table 15 and 15a.

Data on number of seeds per pod revealed that methods of planting significantly influenced number of seeds per pod. The highest number of seeds per pod was observed in broadcasting (15.12) as against line sowing (14.16).

Weed management practices was significant with respect to number of seeds per pod. Imazethapyr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS (16.48) recorded significantly higher number of seeds per pod followed by HW @ 20 and 40 DAS. Imazethapyr, 40 g/ha @ 15- 20 DAS (13.80) recorded significantly lower number of seeds per pod which was statistically on par with unweeded control (13.9 no.) and imazethapyr + imazamox, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS (14.18 no).

Number of seeds per pod was significantly influenced by interaction effects. Broadcasted plot treated with imazethapyr, 40 g/ha @ 15- 20 DAS *fb* HW @ 40 DAS resulted in significantly higher number of seeds per pod which was on par with line sown plot applied with imazethapyr, 40 g/ha @ 15- 20 DAS *fb* HW @ 40 DAS (16.26 no.). The lowest number of seeds were recorded in line sown plot applied with imazethapyr, 40 g/ha @ 15- 20 DAS.

4.3.5 Pod weight

Pod weight as influenced by different treatments are presented in Table 16 and 16a.

Data recorded on pod weight revealed that, it was significantly influenced by crop establishment methods. Significantly higher pod weight of 1.31g was noted in line sowing followed by broadcasting.

Data on weed management practices indicated that, imazethapyr + imazamox, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS (1.53g) recorded significantly higher pod weight of cowpea which was on par with hand weeding at 20 and 40 DAS and weedy check recorded significantly lower pod weight of 1.11g.

Interaction effect of weed management and crop establishment methods was also significant. Significantly higher pod weight was observed in treatment combination of broadcasting with pre-mix of imazethapyr + imazamox, 40 g/ha @ 15- 20 DAS *fb* HW @ 40 DAS, followed by line sowing with application of pre-mix of imazethapyr + imazamox, 40 g/ha @ 15-20 DAS + HW @ 15-20 DAS .The lowest pod weight was observed in broadcasted plot treated with imazethapyr, 40 g/ha @ 15-20 DAS + HW @ 15-20 DAS .

4.3.6 Yield

Data on the effect of treatments on yield is given in Table 16 and Table 16a.

Data on crop establishment methods revealed that line sowing recorded significantly higher yield of 741.89 kg/ha as compared with 717.22 kg/ha of grain cowpea from broadcast method of sowing.

Weed control practices had significant effect on yield of grain cowpea. Hand weeding @ 20 and 40 DAS recorded significantly higher yield of 937.66 kg/ha, followed by treatment of imazethapyr + imazamox, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS (877.33 kg/ha). Weedy check recorded significantly lower yield of 281.83 kg/ha.

Interaction effect was significant with respect to grain yield. The highest yield was recorded from plots where hand weeding was done twice in line sown plot followed by broadcasted plot where two hand weeding were combined. Significantly lower yield was registered in weedy check.

Table 10. Effect of crop establishment methods and weed management practices on plant height

Plant height (cm)		
Treatments	**30 DAS**	**60 DAS**
Crop establishment methods		
Broadcasting	68.30	120.23
Line sowing	73.10	139.24
SE (m)	0.83	4.99
CD (0.05)	2.45	14.37
Weed management practices		
HW @ 20 and 40 DAS	72.52	135.20
Imzr+imzx, 40 g/ha @15-20 DAS	76.98	125.98
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	79.53	134.88
Imzr, 40 g/ha @ 15- 20 DAS	68.53	123.48
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	69.40	136.10
Unweeded control	57.27	122.75
SE (m)	1.45	
CD (0.05)	4.24	NS

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

Table 11. Effect of crop establishment methods and weed management practices on number of branches per plant

Treatments	Number of branches	
	30 DAS	60 DAS
Crop establishment methods		
Broadcasting	3.46	8.34
Line sowing	2.41	7.90
SE (m)	0.15	0.14
CD (0.05)	0.45	0.41
Weed management practices		
HW @ 20 and 40 DAS	2.37	7.63
Imzr+imzx, 40 g/ha @15-20 DAS	3.20	7.93
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	2.80	8.65
Imzr, 40 g/ha @ 15- 20 DAS	3.20	8.10
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	3.10	8.40
Unweeded control	2.93	8.03
SE (m)		
CD (0.05)	NS	NS

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

Table 12. Effect of crop establishment methods and weed management practices on number of leaves

Treatments	Number of leaves	
	30 DAS	**60 DAS**
Crop establishment methods		
Broadcasting	18.05	48.57
Line sowing	20.44	47.74
SE (m)	0.57	
CD (0.05)	1.66	NS
Weed management practices		
HW @ 20 and 40 DAS	19.38	47.27
Imzr+imzx, 40 g/ha @15-20 DAS	19.68	48.60
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	18.98	48.73
Imzr, 40 g/ha @ 15- 20 DAS	19.82	48.55
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS		
Unweeded control	17.33	48.50
SE (m)		
CD (0.05)	NS	NS

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

Table 13. Effect of crop establishment methods and weed management practices on leaf area index and total dry matter production at harvest

Treatments	Leaf area index			DMP at harvest(kg/ha)
	20 DAS	40 DAS	60 DAS	
Crop establishment methods				
Broadcasting	2.37	6.09	7.74	4501.51
Line sowing	1.42	3.55	4.50	4377.81
SE (m)	0.03	0.06	0.06	
CD (0.05)	0.07	0.18	0.16	NS
Weed management practices				
HW @ 20 and 40 DAS	1.93	4.76	5.90	4276.71
Imzr+imzx, 40 g/ha @15-20 DAS	1.86	4.81	6.21	4488.63
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	1.78	4.86	6.28	4762.75
Imzr, 40 g/ha @ 15- 20 DAS	1.91	5.04	6.33	4625.69
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	1.96	5.13	6.20	5084.68
Unweeded control	1.92	4.34	5.77	3399.50
SE (m)		0.108	0.094	241.48
CD (0.05)	NS	0.32	0.28	708.24

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

Table 14. Effect of crop establishment methods and weed management practices on days to 50% flowering and 100 grain weight

Treatments	Days to 50% flowering	100 grain weight (g)
Crop establishment methods		
Broadcasting	33.17	10.91
Line sowing	31.67	10.93
SE (m)	0.12	
CD (0.05)	0.37	NS
Weed management practices		
HW @ 20 and 40 DAS	32.17	11.08
Imzr+imzx, 40 g/ha @15-20 DAS	32.67	10.45
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	32.17	10.65
Imzr, 40 g/ha @ 15- 20 DAS	32.67	11.50
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	32.50	11.57
Unweeded control	32.33	10.26
SE (m)		0.18
CD (0.05)	NS	0.54

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

Table 14a. Interaction effect of crop establishment methods and weed management practices on 100 grain weight

Treatments	100 grain weight (g)
Broadcasting	
HW @ 20 and 40 DAS	9.34
Imzr+imzx, 40 g/ha @15-20 DAS	11.06
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	11.17
Imzr, 40 g/ha @ 15- 20 DAS	11.22
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	11.40
Unweeded control	11.26
Line sowing	
HW @ 20 and 40 DAS	11.18
Imzr+imzx, 40 g/ha @15-20 DAS	9.82
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	10.13
Imzr, 40 g/ha @ 15- 20 DAS	11.79
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	11.74
Unweeded control	10.91
SE (m)	0.26
CD (0.05)	0.76

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding,

Table 15. Effect of crop establishment methods and weed management practices on number of pod per plant and number of seed per pod

Treatments	Number of pods per plant	Number of seeds per pod
Crop establishment methods		
Broadcasting	37.61	15.12
Line sowing	37.83	14.16
SE (m)		0.14
CD (0.05)	NS	0.42
Weed management practices		
HW @ 20 and 40 DAS	41.66	15.00
Imzr+imzx, 40 g/ha @15-20 DAS	36.00	14.48
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	42.16	14.17
Imzr, 40 g/ha @ 15- 20 DAS	35.67	13.80
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	39.33	16.48
Unweeded control	31.50	13.90
SE (m)	0.48	0.25
CD (0.05)	1.41	0.74

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

Table 15a. Interaction effect of crop establishment methods and weed management practices on number of pod per plant and number of seed per pod

Treatments	Number of pods per plant	Number of seeds per pod
Broadcasting		
HW @ 20 and 40 DAS	41.33	15.63
Imzr+imzx, 40 g/ha @15-20 DAS	35.00	14.30
Imzr+imzx, 40g/ha @15-25 DAS *fb* HW@ 40 DAS	42.00	14.67
Imzr, 40 g/ha @ 15- 20 DAS	34.00	15.16
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	40.33	16.70
Unweeded control	33.00	14.23
Line sowing		
HW @ 20 and 40 DAS	42.00	14.36
Imzr+imzx, 40 g/ha @15-20 DAS	37.00	14.67
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	42.33	13.66
Imzr, 40 g/ha @ 15- 20 DAS	37.35	12.43
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	38.38	16.26
Unweeded control	30.00	13.56
SE (m)	0.68	0.35
CD (0.05)	1.99	1.04

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

Table 16. Effect of crop establishment methods and weed management practices on pod weight and yield

Treatments	Pod weight(g)	Yield(kg/ha)
Crop establishment methods		
Broadcasting	1.26	717.22
Line sowing	1.31	741.89
SE (m)	0.01	1.79
CD (0.05)	0.04	5.24
Weed management practices		
HW @ 20 and 40 DAS	1.49	937.67
Imzr+imzx, 40 g/ha @15-20 DAS	1.18	715.02
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	1.53	877.30
Imzr, 40 g/ha @ 15- 20 DAS	1.24	723.50
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	1.16	841.67
Unweeded control	1.11	281.83
SE (m)	0.02	3.09
CD (0.05)	0.06	9.07

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

Table 16a. Interaction effect of crop establishment methods and weed management practices on pod weight and yield

Treatments	Pod weight (g)	Yield (kg/ha)
Broadcasting		
HW @ 20 and 40 DAS	1.48	923.67
Imzr+imzx, 40 g/ha @15-20 DAS	1.14	706.00
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	1.53	862.64
Imzr, 40 g/ha @ 15- 20 DAS	1.25	710.33
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	1.08	819.67
Unweeded control	1.10	281.00
Line sowing		
HW @ 20 and 40 DAS	1.51	951.62
Imzr+imzx, 40 g/ha @15-20 DAS	1.22	724.65
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	1.52	892.00
Imzr, 40 g/ha @ 15- 20 DAS	1.22	736.60
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	1.25	863.67
Unweeded control	1.13	282.67
SE (m)	0.03	4.38
CD (0.05)	0.09	12.83

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

4.4. Uptake of N, P_2O_5 and K_2O by crop

Effect of treatments on uptake of N, P_2O_5 and K_2O by crop are presented in Table 17 and 17a.

Method of planting was non significant with respect to nitrogen uptake by crop. Among weed control treatments significantly higher N uptake was observed in imazethapyr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS (157.90 kg/ha) was on par with hand weeding twice. Imazethapyr + imazamox, 40 g/ha @ 15-20 DAS shown significantly lower uptake. Treatment combination of line sowing with application of imazethapyr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS showed significantly higher uptake of nitrogen (161.13 kg/ha) followed by broadcasted plot where hand weeding done twice. The lowest uptake was observed in line sown weedy check.

Uptake of phosphorus by crop was not significantly influenced by method of planting. Between weed management practices, hand weeding @ 20 and 40 DAS shown significantly higher uptake of phosphorus followed by imazethapyr + imazamox, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS. Interaction effect had no significant impact on uptake of phosphorus.

Potassium uptake was not significantly influenced by method of planting, weed management practices and interaction of method of planting and weed management practices.

4.5 Soil chemical properties

4.5.1 Available N, P_2O_5 and K_2O

Data on available N, P_2O_5 and K_2O are presented in Table 18 and 18a.

Available soil nitrogen was not significantly influenced by main effect of crop establishment methods. Weed management practices were significantly influenced available nitrogen content in soil. Imazethapyr + imazamox, 40 g/ha @ 15-20 DAS recorded significantly higher available nitrogen of 194.76 kg/ha followed by pre-mix of imazethapyr + imazamox, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS (189.94 kg/ha). Unweeded control recorded the lowest available nitrogen of 174.32 kg/ha. Treatment combination of line sowing with imazethapyr, 40 g/ha @ 15- 20 DAS recorded significantly higher available nitrogen, which was on par with line sown plot applied with pre-mix of imazethapyr + imazamox, 40 g/ha @ 15-20 DAS. Significantly lower available nitrogen was recorded in broadcasted weedy check.

No significant effect of available phosphorus was observed in different crop establishment methods of cowpea. However available phosphorus was significantly influenced by different weed management practices. Imazethapyr + mazamox, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS recorded significantly higher value of available phosphorus followed by hand weeding @ 20 and 40 DAS. Interaction effect had no significant effect on available phosphorus.

Crop establishment methods, weed management practices and their interactions did not shown any significant effect on available potassium.

4.5.2 Soil pH and EC

Effect of treatments on Soil pH and EC are presented in Table 19.

Neither the main effects of crop establishment methods and weed management practices and their interactions could influence the pH and EC of soil.

4.5.3 Soil organic carbon

Soil organic carbon as influenced by various treatments are provided in Table 19 and 19a.

Methods of crop establishments and weed management practices showed significant effect on soil organic carbon. Line sowing recorded significantly higher OC percentage of 1.22 as against broadcast sowing with OC content of 1.09 percentage.

Data on weed management practices showed significantly higher OC content in plot applied with pre-mix of imazethapyr + imazamox, 40 g/ha @ 15- 20 DAS *fb* HW @ 40 DAS (1.36 %). The soil organic content was significantly lower in weedy check, which was on par with imazethapyr, 40 g/ha @ 15- 20 DAS.

Interaction effect was significantly influenced with respect to soil organic carbon. Hand weeding twice in line sown crops recorded the highest OC content. Whereas broadcast sowing with the application of imazethapyr, 40 g/ha @ 15- 20 DAS recorded lower organic carbon of 0.86 percentage.

Table 17. Effect of crop establishment methods and weed management practices on Nutrient uptake by crop

Treatments	N, P_2O_5 and K_2O uptake by crop		
	N(kg/ha)	**P_2O (kg/ha)**	**K_2O (kg/ha)**
Crop establishment methods			
Broadcasting	138.66	26.51	228.05
Line sowing	136.91	27.24	241.72
SE (m)			
CD (0.05)	NS	NS	NS
Weed management practices			
HW @ 20 and 40 DAS	157.25	32.26	244.16
Imzr+imzx, 40 g/ha @15-20 DAS	113.36	23.56	235.33
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	149.02	30.83	240.66
Imzr, 40 g/ha @ 15- 20 DAS	130.08	24.92	223.33
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	157.90	27.89	236.16
Unweeded control	119.13	21.77	229.66
SE (m)	1.27	1.37	
CD (0.05)	3.73	4.00	NS

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

Table 17a. Interaction effect of crop establishment methods and weed management practices on nitrogen uptake by crop.

Treatments	N uptake by crop (kg/ha)
Broadcasting	
HW @ 20 and 40 DAS	160.963
Imzr+imzx, 40 g/ha @15-20 DAS	117.943
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	147.560
Imzr, 40 g/ha @ 15- 20 DAS	127.980
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	154.610
Unweeded control	122.883
Line sowing	
HW @ 20 and 40 DAS	153.547
Imzr+imzx, 40 g/ha @15-20 DAS	108.770
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	150.480
Imzr, 40 g/ha @ 15- 20 DAS	132.173
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	161.127
Unweeded control	115.377
SE (m)	1.8
CD (0.05)	5.28

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

Table. 18. Effect of crop establishment methods and weed management practices on available soil N, P_2O_5 and K_2O

Treatments	Available soil N, K_2O		
	N (kg/ha)	**P_2O_5 (kg/ha)**	**K_2O (kg/ha)**
Crop establishment methods			
Broadcasting	187.43	72.54	260.58
Line sowing	186.84	71.57	258.27
SE (m)			
CD (0.05)	NS	NS	NS
Weed management practices			
HW @ 20 and 40 DAS	187.90	79.30	278.68
Imzr+imzx, 40 g/ha @15-20 DAS	194.76	74.34	238.62
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	189.94	87.40	253.14
Imzr, 40 g/ha @ 15- 20 DAS	188.25	61.87	269.85
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	187.63	67.64	277.09
Unweeded control (W_6)	174.32	61.78	239.17
SE (m)	0.86	0.61	
CD (0.05)	2.57	1.8	NS

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

Table 18a. Interaction effect of crop establishment methods and weed management practices on available soil N, P_2O_5 and K_2O

Treatments	Available soil N and P	
	N(kg/ha)	P_2O_5(kg/ha)
Broadcasting		
HW @ 20 and 40 DAS	193.44	80.14
Imzr+imzx, 40 g/ha @15-20 DAS	195.15	75.69
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	187.89	88.27
Imzr, 40 g/ha @ 15- 20 DAS	181.92	62.61
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	187.49	67.30
Unweeded control	178.66	61.14
Line sowing		
HW @ 20 and 40 DAS	182.37	78.46
Imzr+imzx, 40 g/ha @15-20 DAS	194.36	72.99
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	191.99	86.52
Imzr, 40 g/ha @ 15- 20 DAS	194.58	61.13
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	187.76	67.89
Unweeded control	187.97	62.41
SE (m)	1.24	0.86
CD (0.05)	3.63	2.08

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

Table 19. Effect of crop establishment methods and weed management practices on pH, EC, Organic carbon

Treatments	pH	EC (µs)	OC (%)
Crop establishment methods (E)			
Broadcasting (E_1)	4.43	101.44	1.09
Line sowing (E_2)	4.50	95.78	1.22
SE (m)			0.07
CD (0.05)	NS	NS	0.02
Weed management practices (W)			
HW @ 20 and 40 DAS (W_1)	4.50	100.50	1.33
Imzr+imzx, 40 g/ha @15-20 DAS (W_2)	4.80	93.33	1.04
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS (W_3)	4.19	103.00	1.36
Imzr, 40 g/ha @ 15- 20 DAS(W_4)	4.37	106.00	0.92
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS (W_5)	4.44	99.66	1.35
Unweeded control (W_6)	4.48	89.16	0.92
SE (m)			0.01
CD (0.05)	NS	NS	0.03

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

Table 19a. Interaction effect of crop establishment methods and weed management practices on organic carbon

Weed management practices (W)	**Organic carbon (%)**
Broadcasting	
HW @ 20 and 40 DAS (E_1W_1)	1.22
Imzr+imzx, 40 g/ha @15-20 DAS (E_1W_2)	0.97
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS (E_1W_3)	1.30
Imzr, 40 g/ha @ 15- 20 DAS (E_1W_4)	0.86
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS (E_1W_5)	1.32
Unweeded control (E_1W6)	0.88
Line sowing	
HW @ 20 and 40 DAS (E_2W_1)	1.44
Imzr+imzx, 40 g/ha @15-20 DAS (E_2W_2)	1.12
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS (E_2W_3)	1.43
Imzr, 40 g/ha @ 15- 20 DAS (E_2W_4)	0.99
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS (E_2W_5)	1.38
Unweeded control (E_2W_6)	0.97
SE (m)	0.01
CD (0.05)	0.05

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

4.6 Economics of cultivation

Data on cost of cultivation, gross return, net return and B:C ratio are presented in Table 20 and 20a.

Higher cost of cultivation and gross return were recorded for line sown cowpea. Net return and B:C ratio were the highest in broadcasted cowpea.

Among weed management treatments, hand weeding @ 20 and 40 DAS resulted in higher cost of cultivation (Rs. 103361) and gross return (Rs.18753), but lower B:C ratio (1.83) compared to the herbicide treatments. The highest B:C ratio was observed in imazethapyr + imazamox , 40 g/ha @ 15- 20 DAS *fb* HW @ 40 DAS (2.45). Unweeded control resulted in lower cost of cultivation (Rs. 35828), gross return (Rs. 56433) and B:C ratio (1.59).

Economics of cultivation was influenced by interaction effects. Cost of cultivation (Rs. 112237) was higher in hand weeded line sown plot. The highest net return (Rs.108775.0) and B:C ratio (2.7) were noted in treatment combination of imazethapyr + imazamox , 40 g/ha @ 15- 20 DAS *fb* HW @ 40 DAS in broadcasted plot, which was on par with imazethapyr ,40 g/ha @ 15- 20 DAS *fb* HW @ 40 DAS treated in broadcasted plot. Lower B:C ratio was noted in line sown weedy check.

Table 20. Effect of crop establishment methods and weed management practices on cost of cultivation, gross return, net return and B:C ratio

Treatments	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net Return (Rs/ha)	B:C ratio
Crop establishment methods				
Broadcasting	60761	143444	82683	2.35
Line sowing	76727	148400	71672	1.91
Weed management practices				
HW @ 20 and 40 DAS	103361	187533	84172	1.83
Imzr+imzx, 40 g/ha @15-20 DAS	65627	143066	77439	2.22
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	72605	175466	102861	2.45
Imzr, 40 g/ha @ 15- 20 DAS	64012	144700	80688	2.30
Imzr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS	71032	168333	97301	2.40
Unweeded control	35828	56433	20604	1.59

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

Price of grain (as seed)- Rs.200/Kg
Labour charge - Rs. 628/day

Urea- Rs.7/Kg
Factomphos-Rs.20/Kg
MOP- Rs.19/Kg
Lime-Rs.20/Kg

Table 20a. Interaction effect of crop establishment methods and weed management cost of cultivation, gross return, net return and B:C ratio

Treatments	Cost of cultivation(Rs/ha)	Gross return(Rs/ha)	Net return(Rs/ha)	B:C ratio
Broadcasting				
HW @ 20 and 40 DAS	94484	184733	90248	1.96
Imzr+imzx, 40 g/ha @15-20 DAS	56786	141200	84413	2.49
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	63758	172533	108775	2.70
Imzr, 40 g/ha @ 15-20 DAS	55133	142066	86933	2.58
Imzr, 40 g/ha @ 15-20 DAS + HW @ 40 DAS	62186	163933	101746	2.63
Unweeded control	32217	56200	23982	1.74
Line sowing				
HW @ 20 and 40 DAS	112237	190333.33	78096	1.69
Imzr+imzx, 40 g/ha @15-20 DAS	74468	144933.33	70465	1.95
Imzr+imzx, 40g/ha @15-20 DAS *fb* HW@ 40 DAS	81452	178400.00	96948	2.19
Imzr, 40 g/ha @ 15-20 DAS	72891	147333.33	74442	2.02
Imzr, 40 g/ha @ 15-20 DAS + HW @ 40 DAS	79878	172733.33	92855	2.16
Unweeded control	39440	56666	17226	1.44

Imzr- Imazethapyr Imzx- Imazamox HW- Hand weeding

Price of grain (as seed)- Rs.200/Kg
Labour charge - Rs.628/day

Urea- Rs.7/Kg
Factomphos-Rs.20/Kg
MOP- Rs.19/Kg
Lime-Rs.20/Kg

Discussion

5. DISCUSSION

The experiment entitled "Crop establishment methods and weed management on productivity of cowpea [*Vigna unguiculata* (L.) Walp.]" was carried out in Agronomy Farm, Vellanikkara. Findings of this experiment are briefly discussed in this chapter.

Increase in production and productivity of cowpea can be achieved by reducing the influence of yield limiting factors such as weeds. The level of weed infestation can be effectively reduced by adopting different physical and chemical methods. Methods of establishment have impact on weed incidence and growth of crop, which can be effectively utilized for achieving yield enhancement of cowpea.

5.1 Effect of weed management and crop establishment methods on weed parameters

Weed count observations revealed that, field was infested with different category of weeds such as broad-leaved weeds, grasses and sedges at different stages of crop growth. Broad- leaved weeds and grassy weeds were dominant in the field and sedges were very less. *Phyllanthus amara, Mimosa pudica, Mitracarpus hirtus, Euphorbia hirta, Scoparia dulcis, Ageratum conyzoides, Borrevia hispida, Cleome burmannii* and *Mollugo sp* were dominant broad-leaved weeds. Where as *Digitaria ciliaris*, *Echinochloa colona*, *Cynodon dactylon* and *Oryza sativa* were the major grassy weeds.

Weed count was significantly influenced by methods of establishment at 30 DAS. Density of broad-leaved weeds, grasses and sedges (8.11, 5.22 and 0.83 no. /m^2) were higher in broadcasted field compared with the line sown plot (5.5, 2.72 and 0.44 no./m^2). In line sowing method, seeds are sown at a particular spacing, the growth of foliage led to sudden canopy closer at this narrow spacing, which will hinder penetration of light causing reduction in germination and growth of weed seedling, this might be a reason for the reduced population of weeds. Ichikawa (2000) opined that crop weed competition will be severe during early period of growth in broadcasting compared with line sowing. According to Kaur and Singh (2017) uniform crop establishment in drill seeding resulted in fast growth which helps in smothering of weed population. Second stage of observation coincided with the maximum vegetative growth of cowpea and this might have increased smothering

action and led to reduced influence of method of planting on weed population. Yazdani *et al.* (2012) observed 22% increase in biomass of weeds in broadcasted field compared with row planted alfalfa.

According to Olsen *et al*. (2005) lower weed population were noted in row planting. Lower weed dry weight (3.50 and 4.66 g/m^2), WI (22.04%) and higher WCE (75.49% and 70.21%) were noted in line sown cowpea compared with broadcasted cowpea having weed dry weight of 5.09 and 4.91 g/m^2, WCE of 64.41% and 88.61% and WI of 24.63 %. Higher weed dry weight and reduced yield in broadcasting method might be a reason for low WCE and high WI. Ashrafi *et al.* (2009), who concluded that line sowing is superior to broadcasting method of planting for effective weed management practices.

Population of different types of weeds were significantly influenced by weed management practices at both stages of observation. The highest weed density and weed dry weight were observed in weedy check was due to unconstrained growth of weeds. The lowest total weed count (5.83 and 3.3 no./m^2) was observed in hand weeding @ 20 and 40 DAS (Figure 5.1), closely followed by imazethapyr, 40 g/ha @15- 20 DAS *fb* HW @ 40 DAS (6.6 & 7.5 no./m^2). This result is in accordance with the findings of Kumar *et al*. (2016) who reported that spraying of imazethapyr showed high suppression of broad-leaved weeds, grasses and sedges. According to Yadav *et al*. (2019) reduced density of *E. colona* and *C. rotundus* was observed by post-emergence application of imazethapyr. Application of imazethapyr 40 g/ha @ 15- 20 DAS recorded 55.5 % higher WCE and 66 % lower WI with respect to weedy check. Imazethapyr 40 g/ha @ 15- 20 DAS *fb* HW at 40 DAS caused 55.5 % higher WCE and 83.5 % lower WI respectively. This indicate favourable influence of hand weeding after weedicide application.

Application of imazethapyr + imazamox, 40 g/ha @ 15-20 DAS *fb* HW @ 40 DAS recorded lower weed dry weight of 2.19 and 3.04 g/m^2 (Figure 5.3), WI of 7.81 % (Figure 5.7) and higher WCE of 80.61 % (Figure 5.5) compared with spraying of pre-mix of imazethapyr + imazamox,40 g/ha @15- 20 DAS. This might be due to the fact that integrated use of herbicides with physical control such as hand weeding cause sustainable reduction of weed load (Lamichhane *et al*., 2017). According to Komal and Yadav, (2015) application of imazethapyr + imazamox,40 g/ha at 20 DAS *fb* one HW @ 40 DAS resulted in higher WCE and lower WI. Values on weed count

and weed dry weight decreased from 30 DAS to 60 DAS in treatments received hand weeding after herbicidal application, this might be due to efficiency of herbicide, HW done at 40 DAS and smothering action of cowpea. Compared with control, pre-mix spraying of imazethapyr + imazamox, 40 g/ha @15- 20 showed 73.24 % and 69.5 % reduction in weed dry weight and 80.1% and 53.87% reduction in weed count, this gave an indication of efficiencyof spraying pre-mix of imazethapyr + imazamox.

The result is in line with the observation made by Deshkari *et al*. (2019), who concluded that imazethapyr + imazamox 75 g/ha at 20 DAS reduced dry weight and density of weeds in soyabean field. Higher WCE (90.34% & 87.38%) and the lowest WI (1.47%) was observed in hand weeding followed by the applicationof imazethapyr + imazamox, 40 g/ha @15- 20 *fb* HW at 40 DAS (WCE of 84.7% & 80.6% and WI of 7.81%). Kumar and Singh (2017) observed that hand weeding resulted in the highest WCE of 82 % and the lowest WI in cowpea. Similar result has been found by Kujur *et al*. (2015), who recorded lower dry weight and weed index in hand weeding. Lower WCE (9.66 % & 38.73 %) and higher WI (Figure 5.7) was recorded in weedy check, where cowpea might have faced severe competition from weeds. Weed dry weight was reduced 80% & 86.5% in plot sprayed with imazethapyr 40 g/ha at 15-20 DAS compared with unweeded control. Similar result was obtained by Yadav *et al*. (2017) who opined that dry weight of weeds in green gram can be reduced by the application of imazethapyr @ 100g/ha. Veeraputhiran *et al*. (2008) and Khairnar *et al*. (2014) also shared the similar conclusion. High efficiency of imazethapyr might be due to its rapid action to hinder cell division in meristematic region.

Total weed count at 30 DAS (Figure 5.2), dry weight of weeds (Figure 5.4), WCE (Figure 5.6)and WI (Figure 5.8) at 30 and 60 DAS were significantly influenced by interaction effect. At 30 DAS, lower values of total weed count, dry weight and higher WCE were recorded in hand weeded line sown plot (4.01 no./m^2, 1.31 g/m^2 and 90.49%), line sown plot applied with pre-mixof imazethapyr + imazamox, 40 g/ha @ 15-20 DAS (4.33 no./m^2, 2.7 g/m^2 , 81.38%) and linesown plot applied with pre-mix of imazethapyr + imazamox, 40 g/ha @ 15-20 DAS+ HW @ 40 DAS (4.33 no./m^2 ,1.53 g/m^2, 86.19%). It could be inferred from the analysis that handweeding in line sown plot or application of herbicide *fb* hand weeding in line sown plot offer sufficient control of weeds in cowpea. Abdulla *et al*. (2008) reported maximum weed dry weight in combination of broadcast sowing and weedy check in maize.

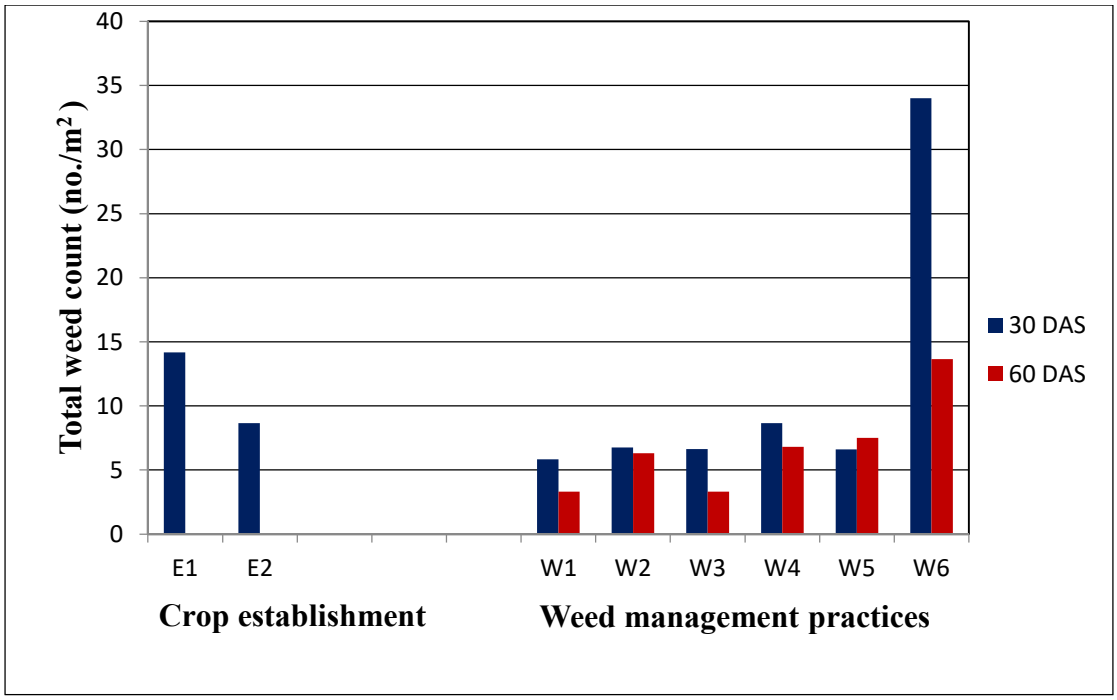


Figure 5.1. Effect of crop establishment methods and weed management on total weed count

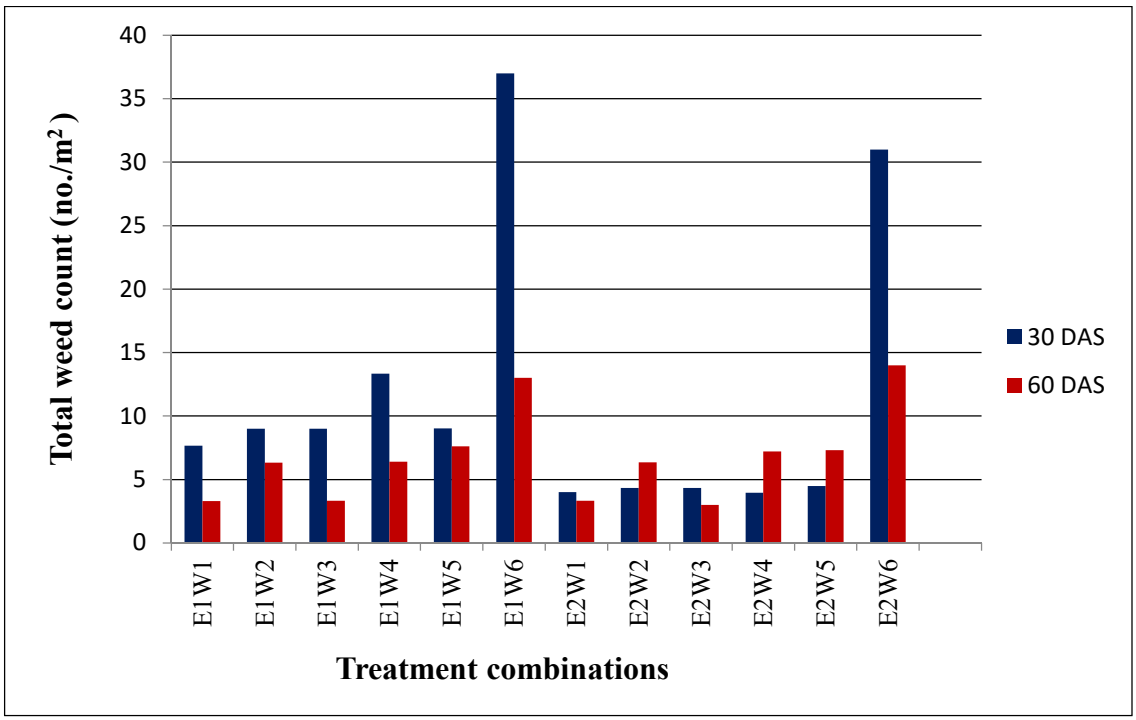


Figure 5.2. Interaction effect of crop establishment methods and weed management on total weed count.

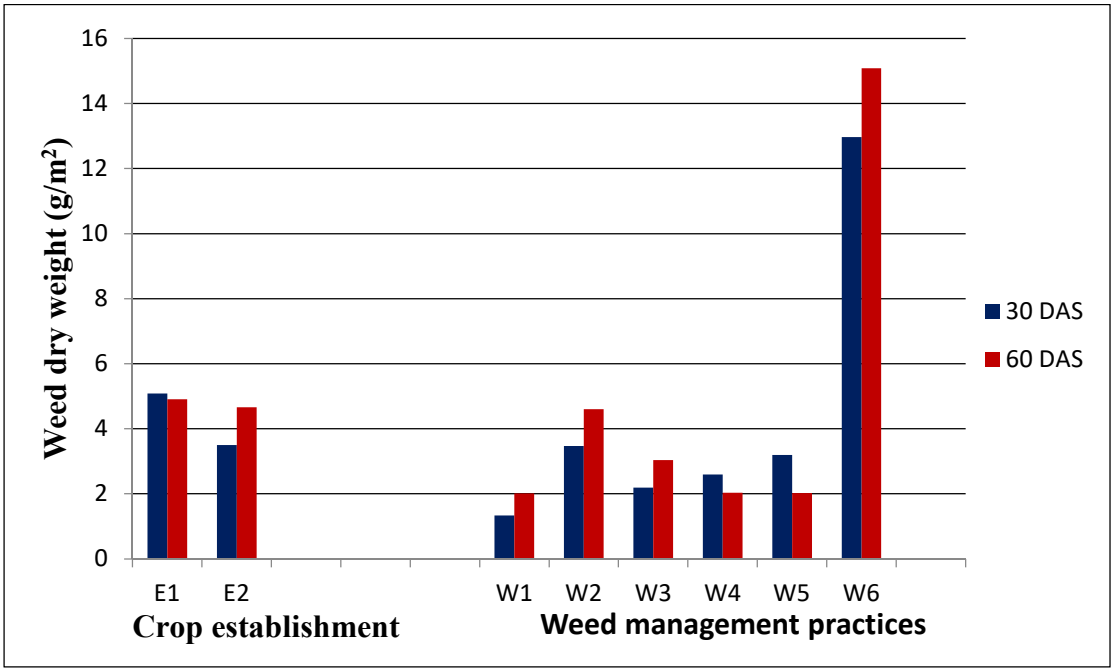


Figure 5.3. Effect of crop establishment methods and weed management on weed dry weight

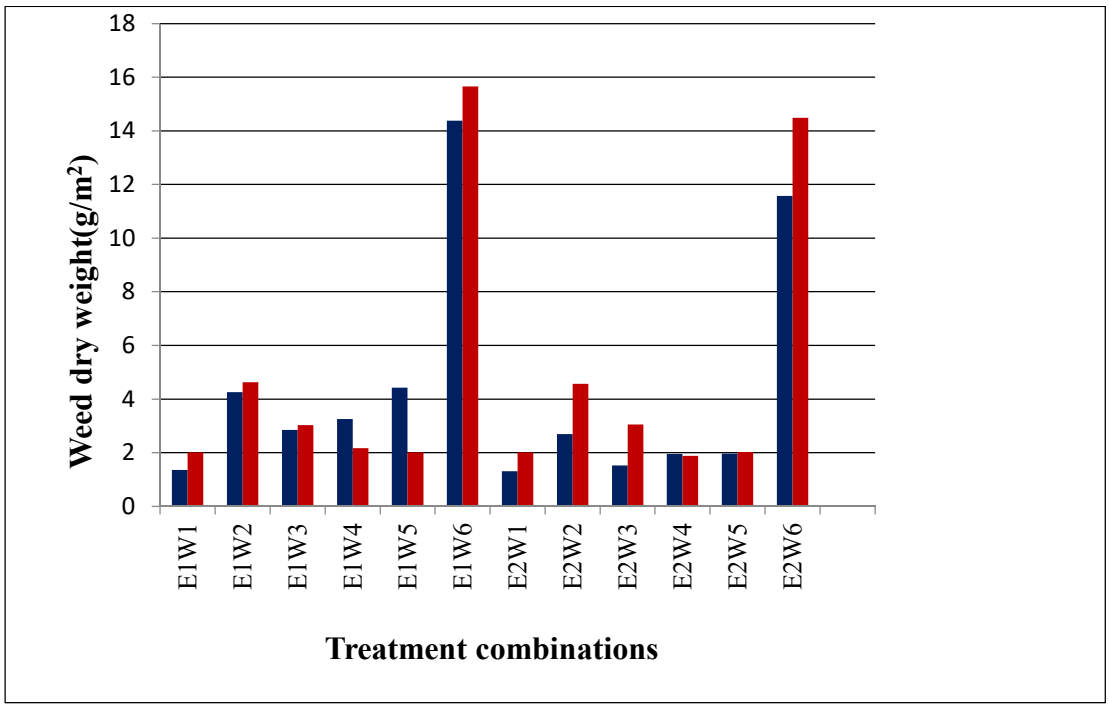


Figure 5.4. Interaction effect of crop establishment methods and weed management on weed dry weight.

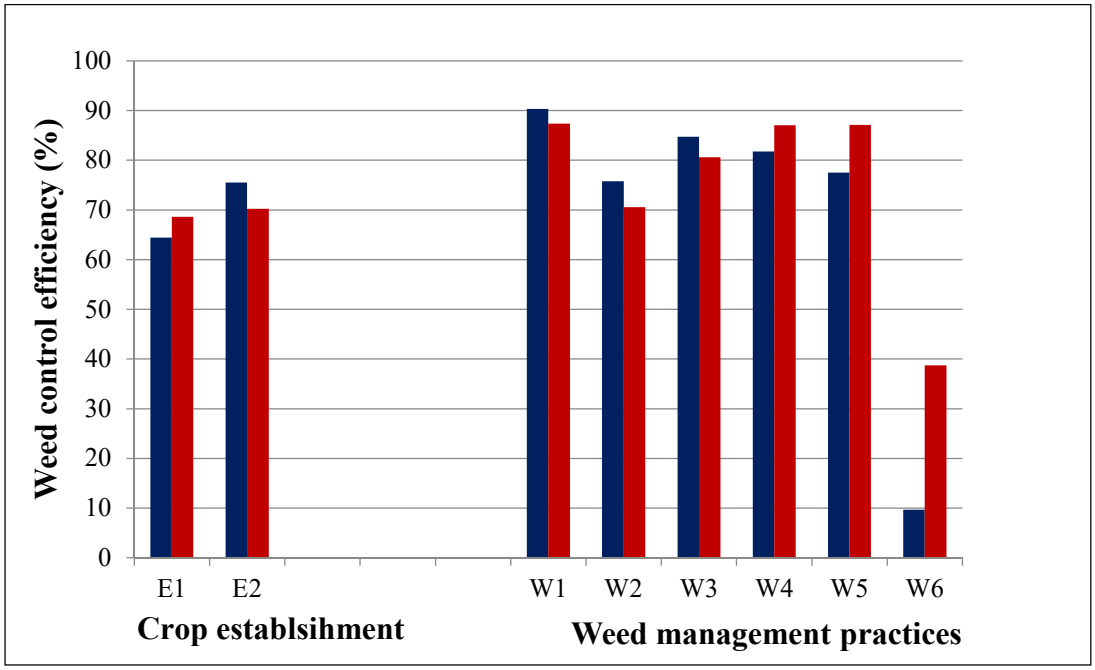


Figure 5.5. Effect of crop establishment methods and weed management on weed control efficiency

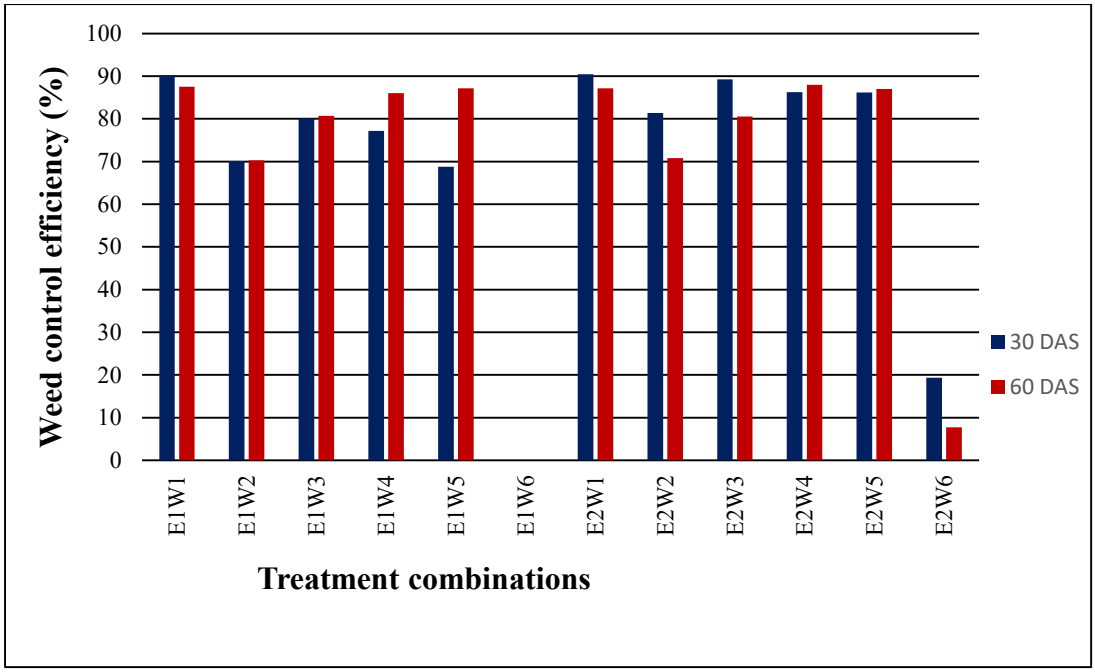


Figure 5.6. Interaction effect of crop establishment methods and weed management on weed control efficiency

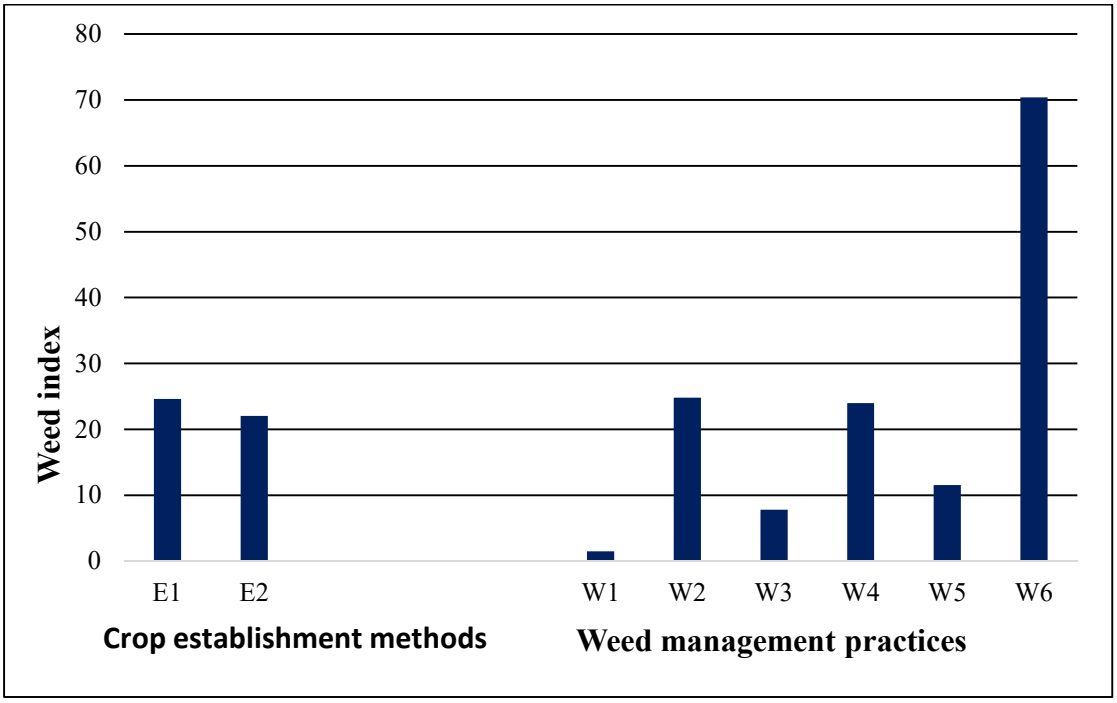


Figure 5.7. Effect of crop establishment methods and weed management on weed index

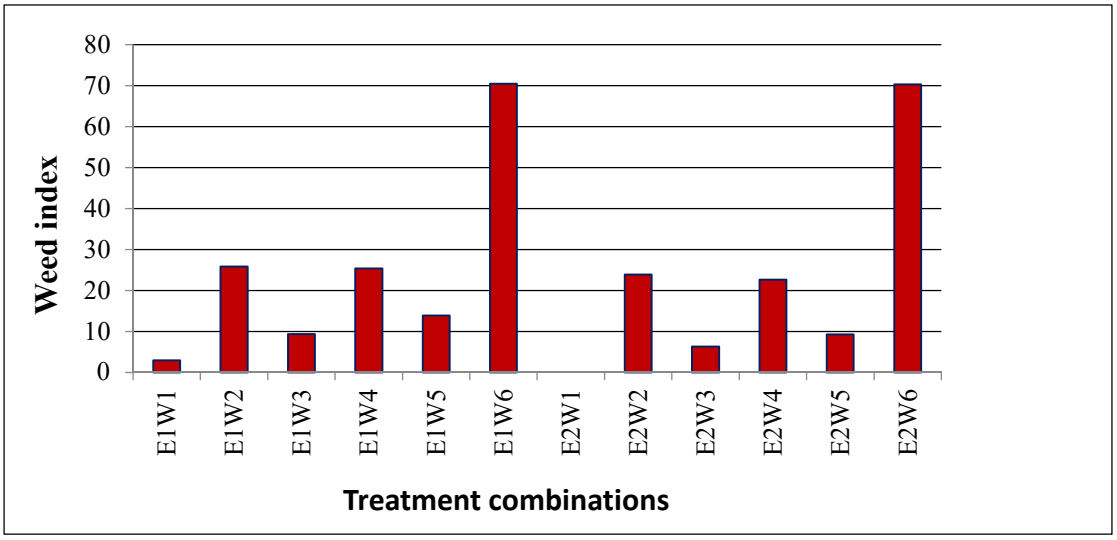


Figure 5.8. Interaction effect of crop establishment methods and weed management on weed index

5.2.Effect of crop establishment method and weed management on growth and productivity of cowpea

Crop establishment methods significantly influenced growth (plant height, number of branches and number of leaves) and yield parameters (days to 50 % flowering, number of seeds per pod, pod weight) of cowpea. The significantly higher yield was obtained from line sown cowpea (717.22 kg/ha) which is 3.3 % higher than broadcasted crop (Figure 5.19). The increase in yield might be due to improved yield attributing characters like number of seeds per pod and pod weight. Decreased weed count and weed dry weight might have led to reduction in CWC (crop weed competition), was finally reflected in yield. Enough space will be available for line sown crops for the better orientation of leaves, which helps to harvest more light resulted in high photosynthetic rate and accumulation of photosynthates which eventually resulted in higher grain yield of cowpea. Line sown plants were the tallest at both stages of observation (Figure 5.9). Height of line sown crop showed an increase of 6.5 % and 13.6 % compared with broadcasted crop. Higher density and scattered arrangement of crops in broadcasted method might have caused competition for resources thereby registering reduction in growth attributes such as plant height. According to Mathew *et al*. (2017) shorter plants were found in broadcasted chickpea. Hamid *et al.* (2002) reported similar findings. Better growth attributes such as height of plant, number of branches and number of leaves have positive influence on nutrient absorption ability and translocation of photosynthates, all these might have paved the way for higher yield of line sown crops. Mohler *et al.* (2001) observed high number of branches, number of leaves, number of pods per plant and seeds per pod in line sown green gram. According to Kumar and Thakur (2005) line sown crops have 10.6 % higher yield than broadcasted crops.

Different growth attributes like height of plant, LAI, dry matter production and yield attributes like 100 grain weight, number of pods per plant, number of seeds per pod, pod weight have significantly influenced by weed management practices. According to Kumar *et al*. (2016) podsper plant were significantly influenced by weed control measures. However number of branches, number leaves, days to 50% flowering was not influenced. Unweeded plot recorded the lowest yield of 281.83 kg/ha, which might be due to CWC which declines the availability of nutrients for crop, thereby decreasing production of branches and leaves. Ultimately 33.14%

reduction in DMP was observed (Figure 5.10). Weedy condition in cowpea resulted in 70% reduction in yield, which is in line with the findings of Mekonnen *et al*. (2016) who reported that weedy condition cause 70.8 % reduction in yield of cowpea. According to Randhawa *et al*. (2002) uncontrolled weeds in field resulted in 46% seed yield reduction in black gram. Similar result has been found by Chaudhary *et al.* (2005) in chickpea, Muhammad *et al*. (2003) in cowpea and Kumar *et al*. (2004) in green gram. Significantly lower values of number of pods (31.50), seeds per pod (13.9) and pod weight (1.11g) were reported from weedy check which might be due to reduced accumulation of photosynthates in crop by heavy weed infestation. Sharma *et al*. (2004) opined that number of seeds per pod will be reduced by weed infestation in beans. Komal and Yadav, (2015) recorded lower number of pods per plant, seeds per pod and seed yield in unweeded control. Uncontrolled growth of weeds in weedy check caused reduced availability of resources for cowpea, which adversely affect the grain yield thereby registering higher weed index of 70.38%.

Hand weeding at 20 and 40 DAS resulted in higher number of pods per plant (Figure 5.13), seeds per pod (Figure 5.15) pod weight (Figure 5.17) and finally yield. This might be due to proper weed control at critical period of CWC, which reduced competition of weeds with cowpea for resources, resulted in proper absorption of nutrients by crop and higher growth parameters and yield. Kumar and Singh (2017) pointed out that higher yield was obtained from cowpea when field was hand weeded. LAI was significantly influenced by weed management practices at 40 and 60 DAS. At 40 DAS, higher LAI was observed in plot applied with imazethapyr at 40g/ha *fb* hand weeding, proper weed control by imazethapyr and hand weeding most likely provided weed free condition during early growth stages resulted in production of higher number of leaves and LAI, which might have enabled to increase accumulation of photosynthates and higher DMP (5084.71 kg/ha) and yield.

Application of pre-mix of herbicides of imazethapyr + imazamox, 40 g/ha @15- 20 DAS *fb* HW @ 40 DAS has enhanced grain yield of cowpea from 281.83 to 877.30 kg/ha, *ie*, 68% higher grain yield compared to unweeded control. Yadav *et al*. (2015) concluded that higher seed yield of black gram was obtained from imazethapyr + imazamox @ 0.05 kg/ha treated plot. Sasode *et al.* (2020) reported that post-emergence application of imazethapyr + imzamox 80 g/ha at 20 DAS caused a hike in seed and stover yield of black gram. Tiwari *et al*. (2006) observed considerable

increase in yield of soyabean under the application of imazethapyr + imazamox at 2l/ha. Application of imazethapyr + imazamox 75 g/ha @ 20 DAS found to improve grain yield in soyabean (Deshkari *et al.*, 2019). Higher yield advantage of treatments may be attributed to high pod weight (1.53g), higher seeds per pod (14.17 no) and the highest number of pods per plant (42.16). Effective weed control by imazethapyr + imazamox, during critical period of CWC might have enabled the crop to attain optimum range of growth attributes such as height (134.88 cm), branches (8.65 no.), leaves (48.73 no) and DMP (4762.75 kg/ha) resulted in higher yield. Yield obtained from plot treated with imazethapyr, 40 g/h @ 15- 20 DAS was 61% higher, it might be due to high WCE of 87 % at 60 DAS. Low weed index (9.24 %), indicating higher yield was noted in imazethapyr, 40 g/ha @15- 20 DAS *fb* HW @ 40 DAS with respect to imazethapyr, 40 g/h @ 15- 20 DAS (22.59%). This was due to the fact that hand weeding will improve soil structure in rhizosphere which facilitate root growth of crop and absorption of nutrients, and the highest DMP of 5084.68 kg/ha. All these factors contributed to higher yield in imazethapyr, 40 g/ha @15- 20 DAS *fb* HW @ 40 DAS.

Interaction effect was found significant for 100 grain weight (Figure 5.12), pods per plant (5.14), seeds per pod (5.16), pod weight (5.17/0 and yield (5.20). The significantly higher yield was obtained from line sown crop that received hanweeding twice at 20 and 40 DAS (951.66 kg/ha) closely followed by hand weeding done in broadcasted plot (923.66 kg/ha). This was due to the beneficial effect of manual weeding done at two different stages of growth. Reduced competition from weeds might have facilitated the crop to achieve high production by making more inputs available to crop. It might be attributed to the high WCE of 90.20 % and 90.49 % during critical period of CWC. The result revealed that proper method of sowing and efficient weed control during early growth stages are essential for attaining yield potential of crop. Shah *et al*. (2018) reported that maximum grain yield was achieved, where manual weeding was done for line sown wheat followed by manual weeding done in bed sowing. Higher pod weight of 1.51 g was recorded in hand weeded line sown plot. This was owing to beneficial effect of line sowing coupled with two hand weeding. Line sowing with premix of imazethapyr + imazamox, 40 g/ha @ 15-20 DAS + HW @ 15-20DAS also showed its potential for higher production as evident from the data on pod weight and number of pods per plant.

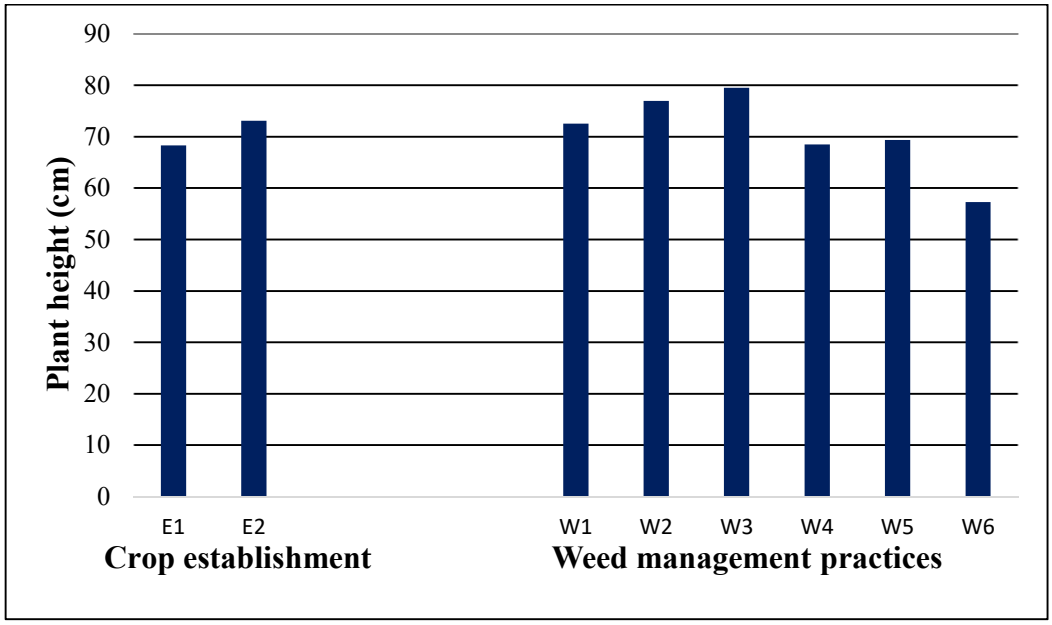
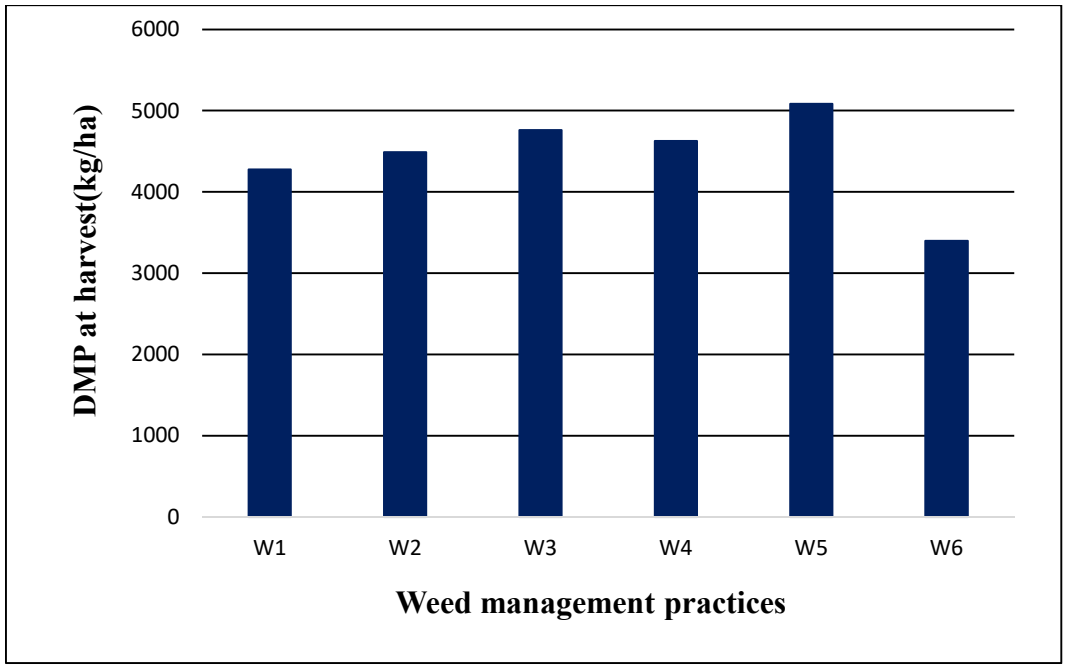


Figure 5.9. Effect of crop establishment methods and weed management on plant height



5.10. Effect of weed management on total dry matter production at harvest

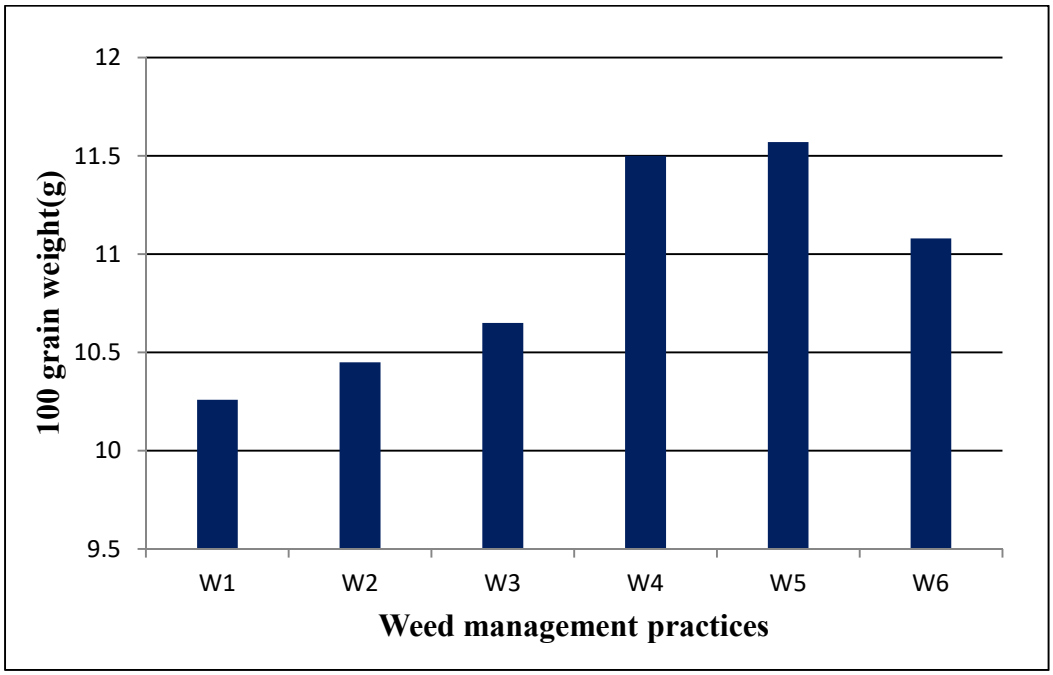


Figure 5.11. Effect of weed management practices on 100 grain weight of cowpea

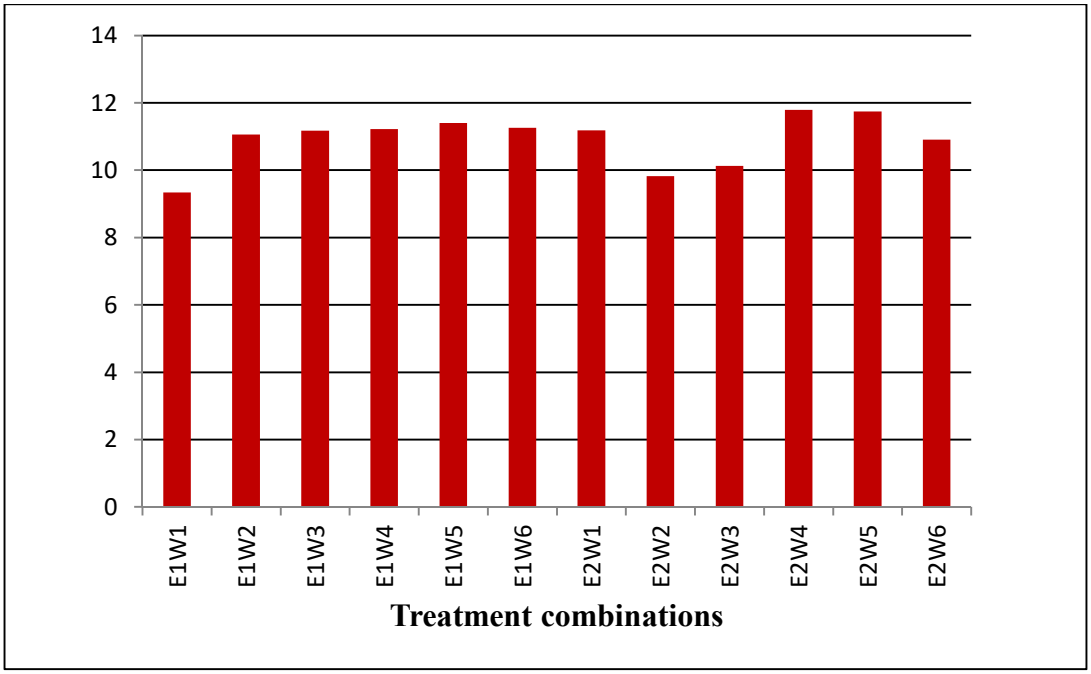


Figure 5.12. Interaction effect of crop establishment methods and weed management on 100 grain weight

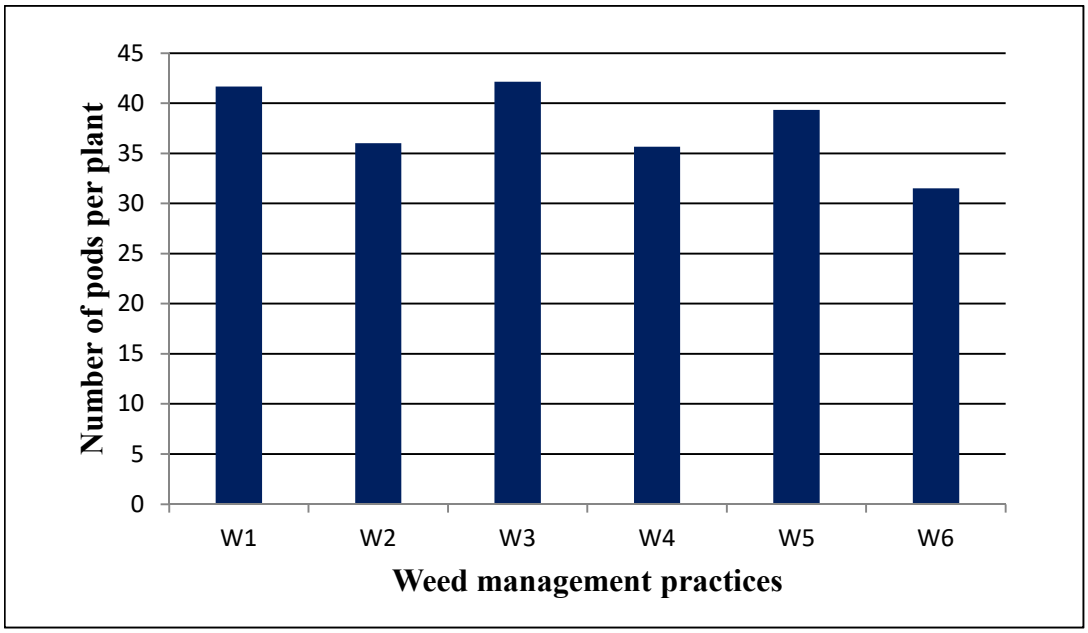


Figure 5.13. Effect of weed management on number of pods per plant

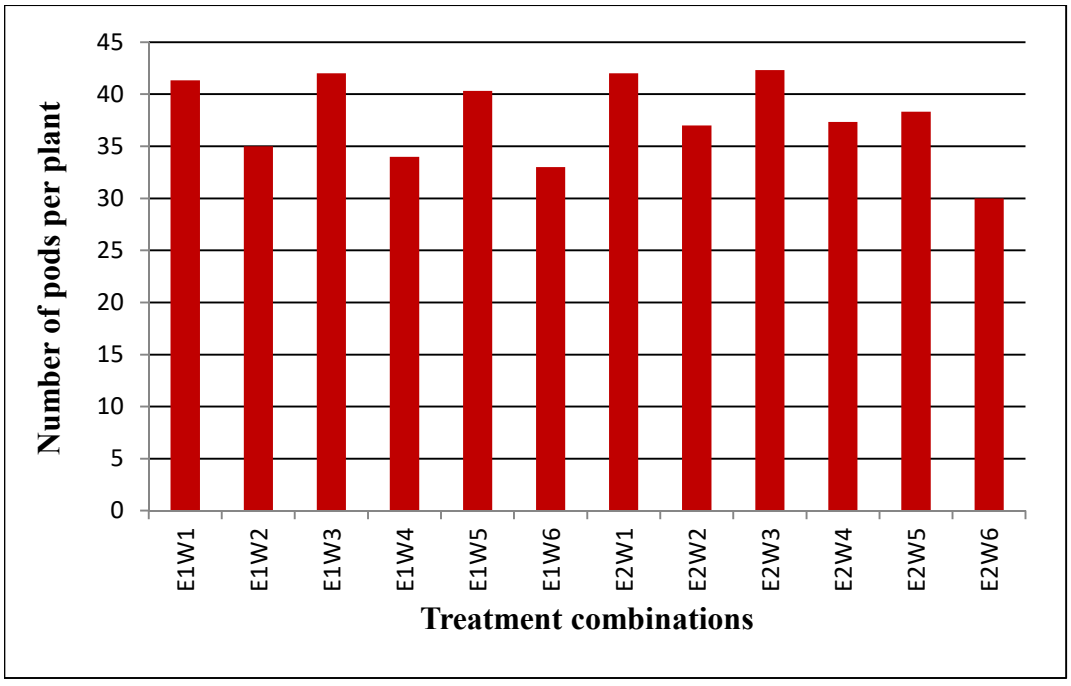


Figure 5.14. Interaction effect of crop establishment methods and weed management on number of pods per plant

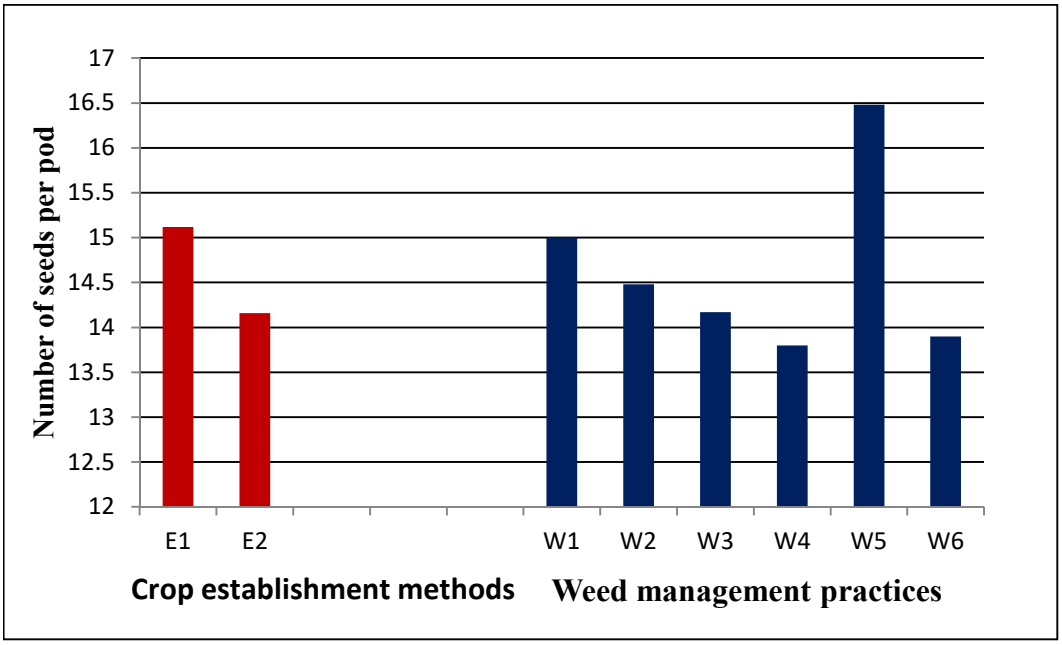


Figure 5.15. Effect of crop establishment methods and weed management on number of seeds per pod

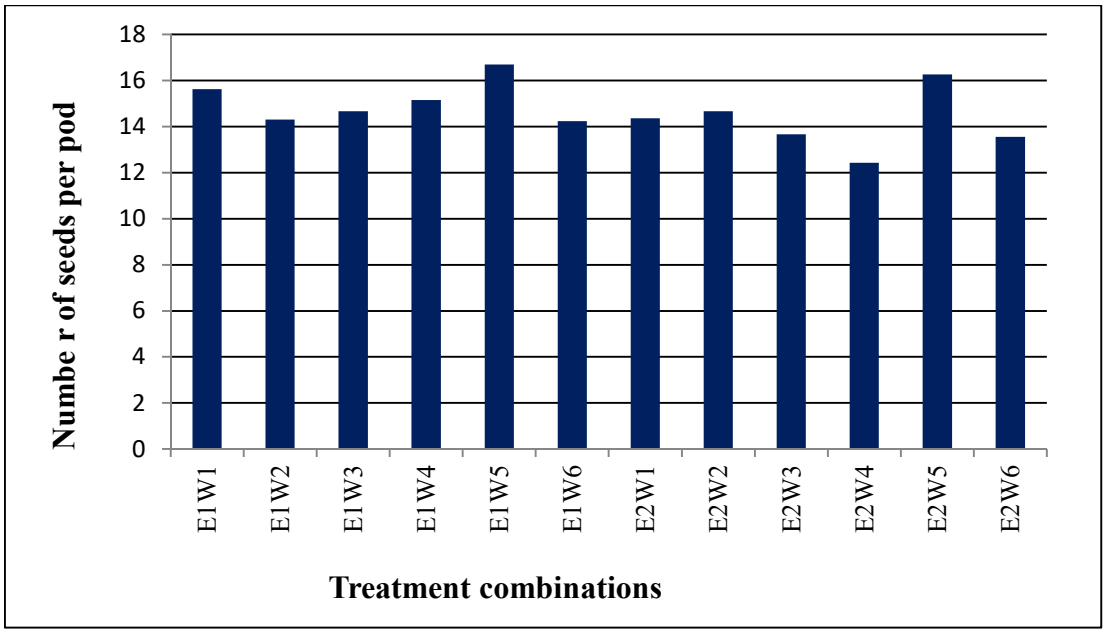


Figure 5.16. Interaction effect of crop establishment methods and weed management on seeds per pod

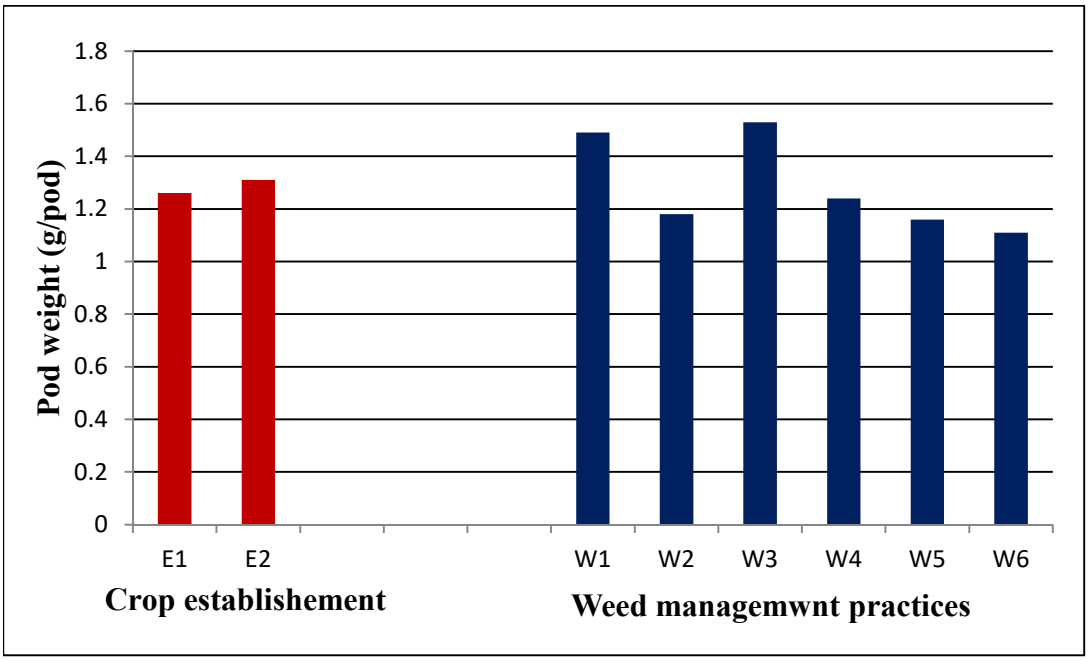


Figure 5.17. Effect of crop establishment methods and weed management on pod weight

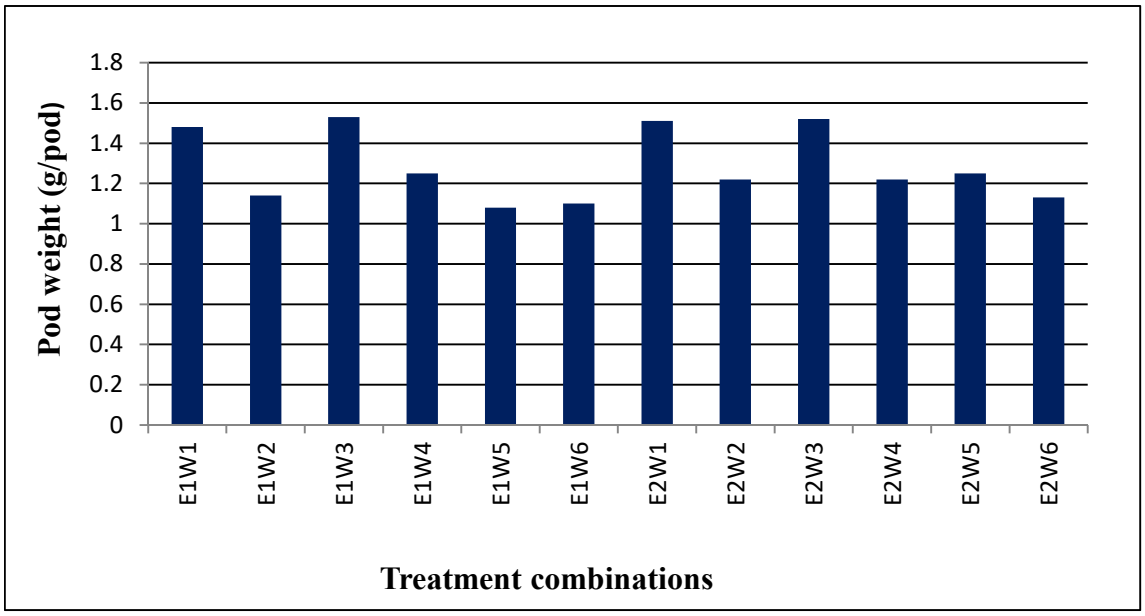


Figure 5.18. Interaction effect of crop establishment methods and weed management on pod weight

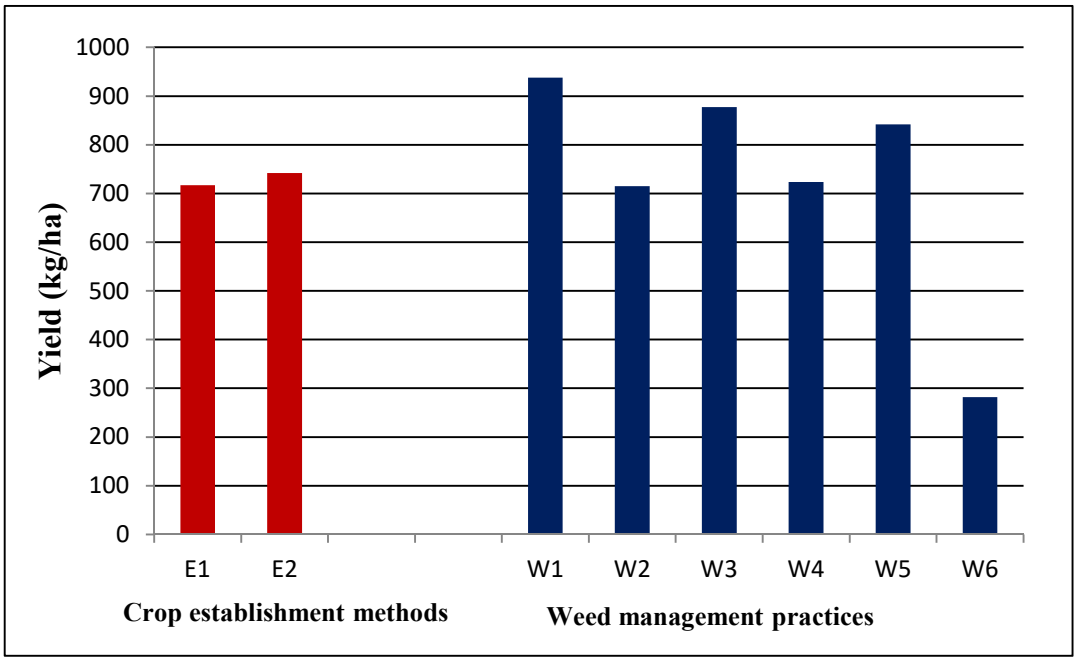


Figure 5.19. Effect of crop establishment methods and weed management on yield

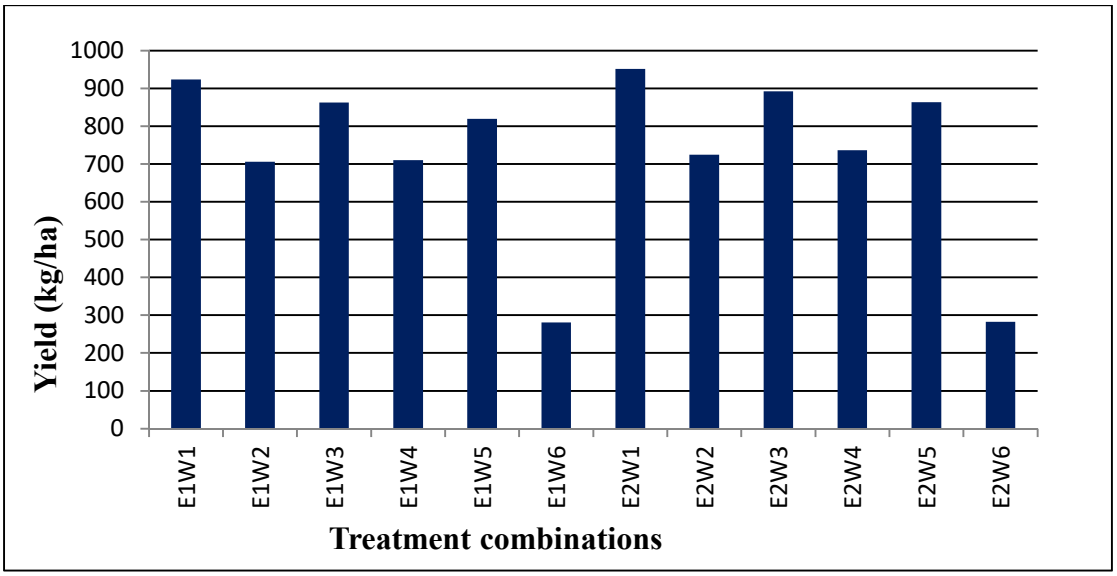


Figure 5.20. Interaction effect of crop establishment methods and weed management on yield

5.3 Effect of crop establishment methods and weed management on nutrient status of soil

Crop establishment methods did not have any significance on pH, EC and availability of N, P and K. However, organic carbon was significantly influenced by treatments .Organic carbon content of soil after cultivation has found to increase in field. This may be attributed to the addition of cow dung and decomposition of previous crop residues, which might have added organic matter to soil. Compared with broadcasted field high organic carbon was recorded in line sown area. Reduced weed growth in line sown plots might have enabled the crop to grow vigorously and release organic substances to soil as root exudates. Organic carbon content in soil was also significantly affected by weed management practices (Figure 5.23). Higher organic carbon was observed in imazethapyr + imazamox, 40g/ha on 15- 20 DAS HW @ 40 DAS which was on par with imazethapyr and HW @ 40 DAS. Which might be attributed to the efficient weed control by treatments, which consequently improved growth of crops.

Weed management practices significantly influenced available N and P after the experiment (Figure 5.21). The highest value of available nitrogen was recorded in imazethapyr + imazamox, 40g/ha on 15- 20 DAS (194.76 kg/ha) *fb* HW @ 20 & 40 DAS (189.94 kg/ha). Adoption of proper weed management practices with herbicides might have decreased weed infestation, caused lower DMP of weed and reduced removal of nutrients as reflected in data on availability of N and P (Figure 5.21). Sinchana, (2020) opined that weed infestation in green gram resulted in low availability of N and P. Amount of available nitrogen was very less in weed check (174.32 kg/ha), where weeds might have removed huge quantity of nutrients there by adverselyaffecting growth and yield of crop. Ravikiran (2018), Dayaram (2013) and Basila (2018) also shared the similar findings. The highest available P was noted in plot applied with imazethapyr+ imazamox, 40 g/ha @15- 20 DAS *fb* HW @ 40 DAS and the lowest in unweeded control which was on par with imazethapyr, 40 g/ha @ 15- 20 DAS, it may be attributed to the inefficient weed control of this treatment. Unconstrained growth of weeds might have absorbed lot of nutrients resulted in the lowest value of available N, P and K (174.32, 61.78 and 239.17kg/ha) in unweeded control.

Interaction effect was significant for the availability of N and P (Figure 5.22). Pre-mix of imazethapyr + imazamox, 40 g/ha @ 15-20 DAS applied in broadcasted plot recorded higher amount of available nitrogen followed by imazethapyr, 40 g/ha @ 15- 20 DAS in line sown plot. Reduced CWC must have increased available nutrients compared with control.

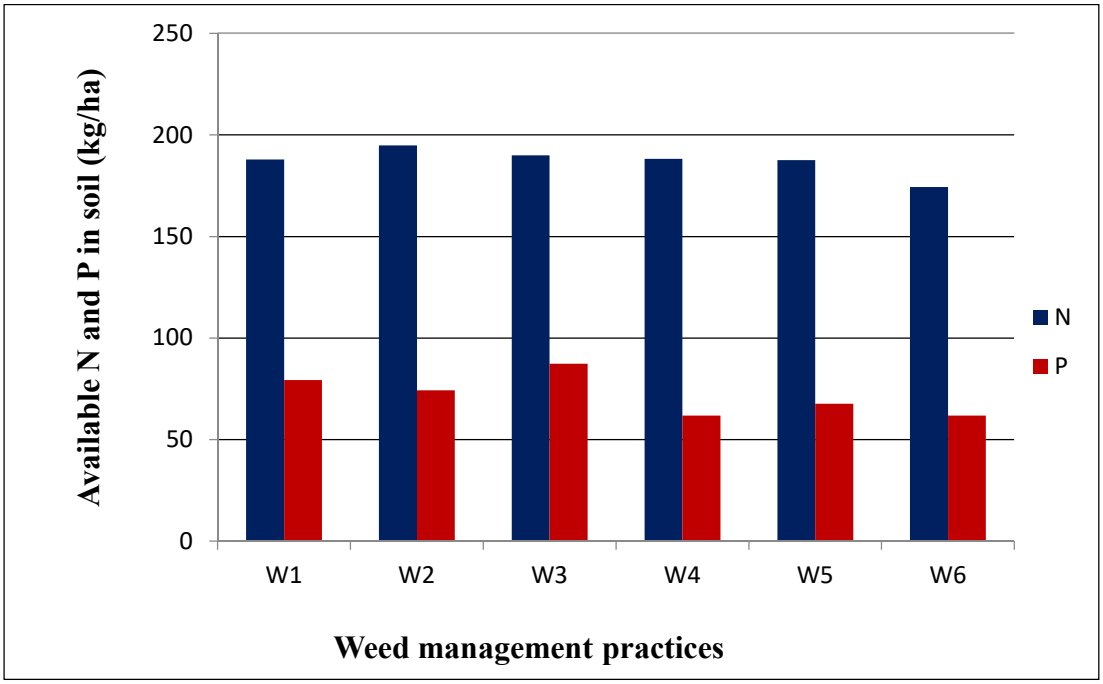


Figure 5.21. Effect of weed management on available N and P

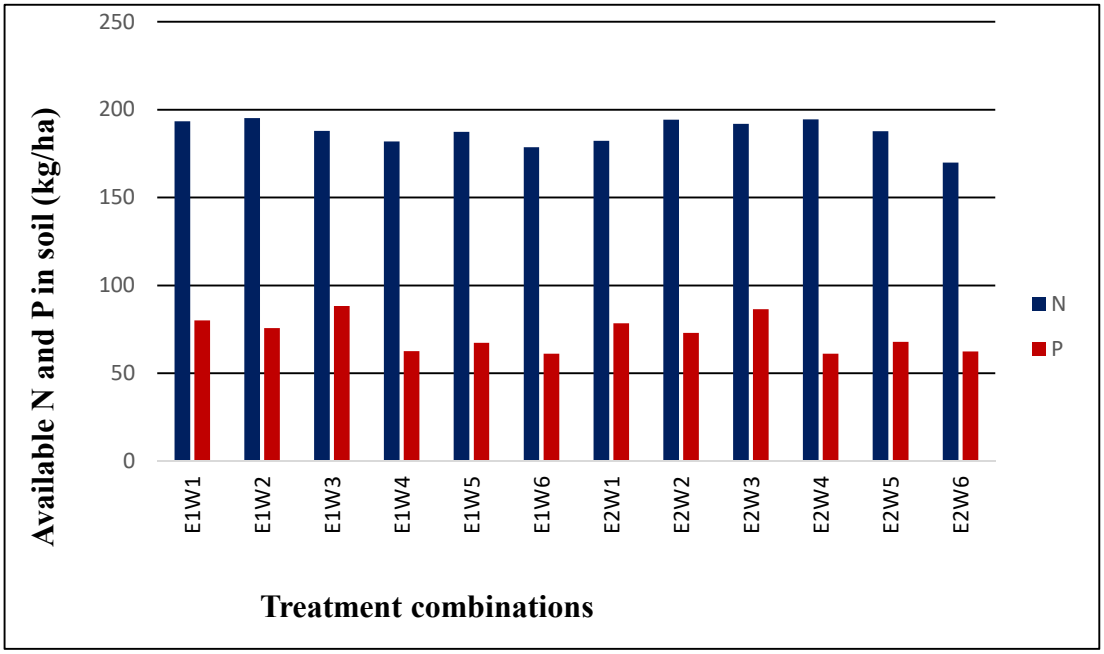


Figure 5.22. Interaction effect of crop establishment methods and weed management on available N and

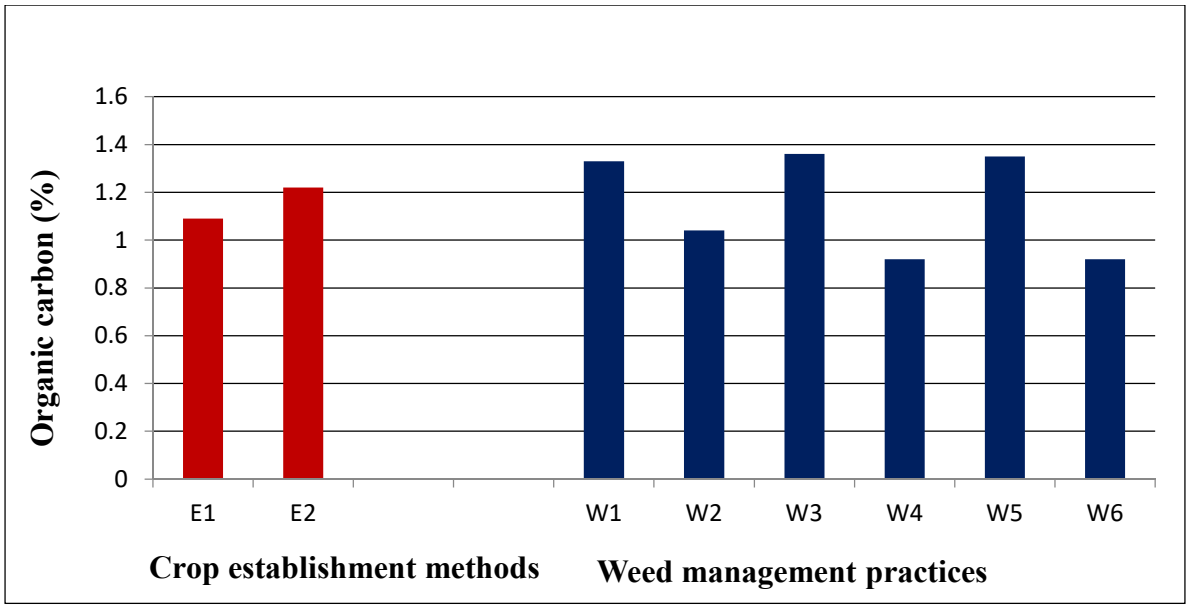


Figure 5.23. Effect of crop establishment methods and weed management on organic carbon content

5.4 Effect of crop establishment methods and weed management on nutrient uptake bycrop

N, P_2O_5 and K_2O uptake of crop significantly not affected by method of planting. Weed management practices have increased N uptake by 24.2 % and P uptake by 32.5% (Figure 5.24). Nutrient absorption by crop was severly hamperd by weeds, which is confirmed by the reduced absorption of nutrients by crop in unweeded plot (119.13 and 21.77 kg/ha of N and P). Amount of nutrient removed by weeds can be effectively utilized by crop if weeds are managed properly. It is evident from the data on amount of nutrient absorbed by crops in different treatments. The highest uptake of N was observed in imazethapyr, 40 g/ha @15- 20 DAS *fb* HW @ 40 DAS closely followed by hand weeding twice. Kujur *et al.* (2015) also revealed that uptake of nutrient was higher in herbicide treated and hand weeded plots. Sinchana, *et al*. (2020) reported that weed management practices caused higher NPK uptake over control. Application of imazethapyr + imazamox, 40 g/ha @15- 20 DAS *fb* HW @ 40 DAS resulted in 23.92 % higher uptake of nutrient compared to imazethapyr + imazamox, 40 g/ha @15- 20 DAS, which might be owing to the fact that herbicidal application followed by hand weeding is superior in achieving effective weed control. Tiwari *et al*. (2006) also reported higher NPK uptake of soyabean by the post emergence application of imazethapyr + imazamox.

Interaction effect was significant for N uptake (Figure 5.25). Significantly higher uptake was observed for line sown plot treated with imazethapyr, 40 g/ha @ 15- 20 DAS + HW @ 40 DAS, followed by hand weeding in broadcasted plot.

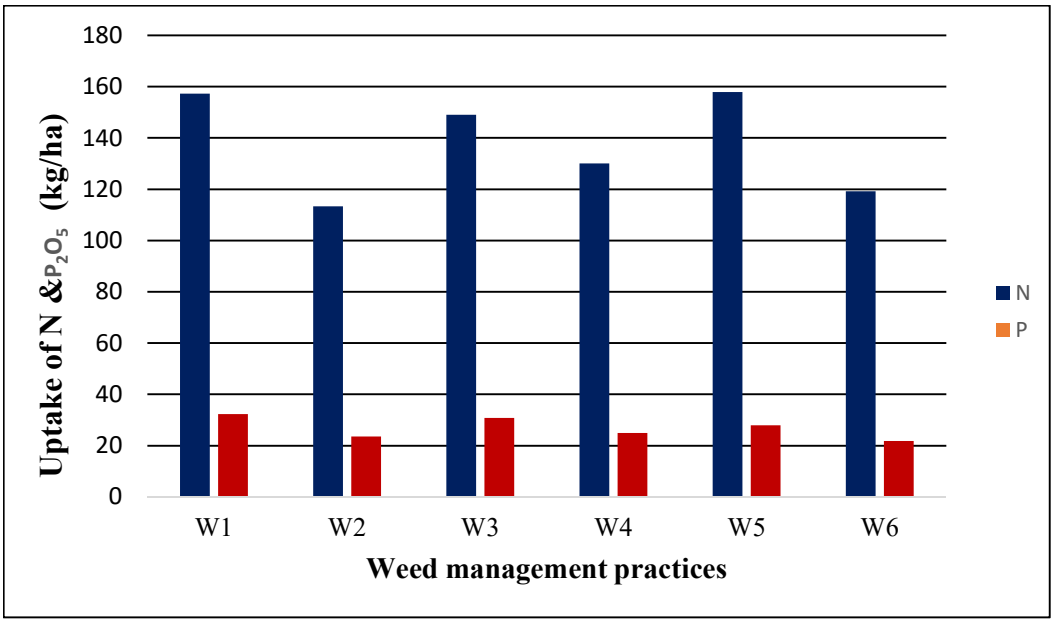


Figure 5.24. Effect of weed management on uptake of N and P_2O_5

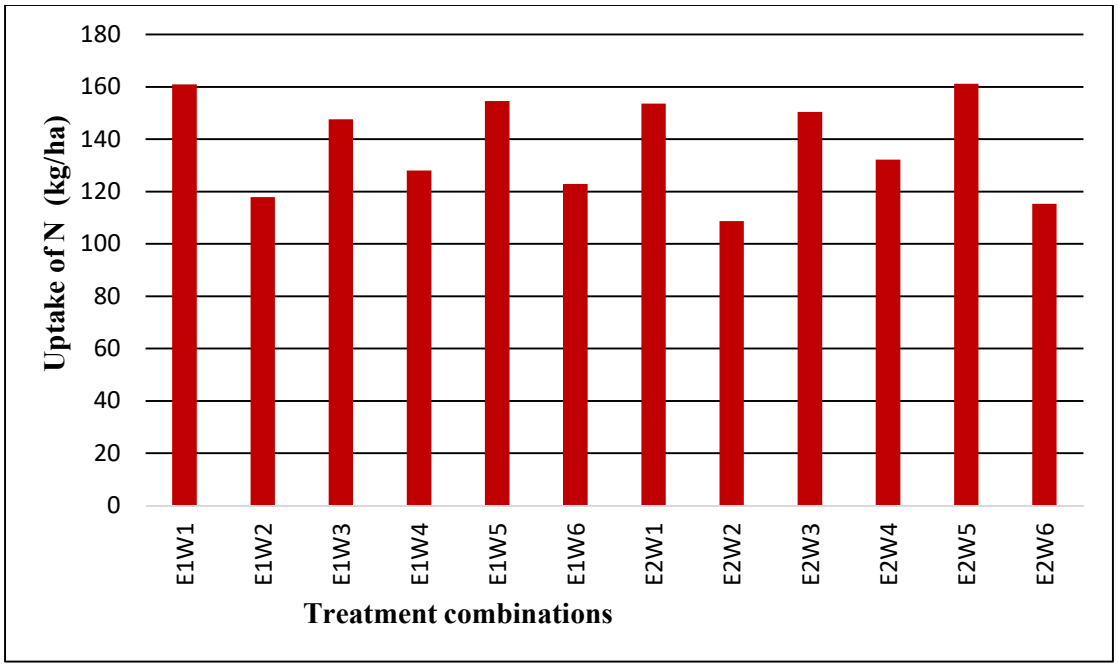


Figure 5.25. Interaction effect of crop establishment methods and weed management on uptake of N

5.5 Economics of cultivation

Economic analysis of different practices adopted, such as crop establishment methods and weed management practices are mandatory to know its usefulness in farmer's field. Broadcasting recorded higher net return (Rs. 82683) and B:C ratio (2.35) compared with line sowing, which recorded net return of Rs. 71672 and B:C ratio of 1.91 (Figure 5.26). It was due to lower cost of cultivation for broadcasted plot. Large number of labours are required for dibbling of seeds and thinning of seedlings in line sown plots, resulted in higher cost of cultivation. Line sown cowpea registered the highest production and gross return, but owing to high labour cost it recorded lower value of B:C ratio compared to broadcasting. Line sowing caused 21 % hike in cost of cultivation than broadcasting. The findings are in line with the conclusion made by Saha *et al.* (2021) who reported that cost of cultivation for manual line sowing was very high compared to drill and broadcast seeding. .

Weed management practices significantly influenced the cost of cultivation, net return and B:C ratio. The highest net return (Rs.108775) and B:C ratio(2.7) were noted in treatment combination of imazethapyr + imazamox , 40 g/ha @ 15- 20 DAS *fb* HW @ 40 DAS in broadcasted plot, which was on par with imazethapyr ,40 g/ha @ 15- 20 DAS *fb* HW @ 40 DAS treated in broadcasted plot. Lower B:C ratio was noted in line sown weedy check. Adoption of weed control measures increased the net return from 20604.50 to 102861 rupees, *i.e*., 80 % increase in net return owing to the increased yield due to weed control. Weed management practices might have reduced weed count and weed dry weight which indicate reduction of CWC, helped the crop to grow with maximum potential and increased absorption of nutrients finally resulted in good yield contributing characters and yield. High grain yield resulted in maximum income. High net income from treated plot than weedy check might be an evidence for the efficiency of adopted weed control measures. Hand weeding @ 20 and 40 DAS resulted in lower weed density, higher yield and gross return. However unavailability of labour at critical period of CWC, high wage of labour and practical difficulty in adopting large area are main reason for reduced dependency on hand weeding. Khan *et al.* (2004) opined that physical methods of weed control are expensive due to high labour cost. The high B:C ratio in imazethapyr + imazamox, 40 g/ha @15- 20 DAS *fb* HW @ 40 DAS and imazethapyr 40 g/ha @15- 20 DAS *fb*

HW @ 40 DAS may be attributed to high efficiency of integrated weed management, *i.e.,* combination of physical and chemical method.

Singh *et al*. (2016) reported that imazaethapyr @ 35 g/ha + imazamox@ 35 g/ha was the best treatment in terms of net return and B:C ratio, followed by the application of imazethapyr at 80 g/ha (Rana *et al.*,2019) .Similar findings was obtained by Mansoori *et al* (2015), Yadav *et al.*(2015) and Gupta *et al.*(2016).

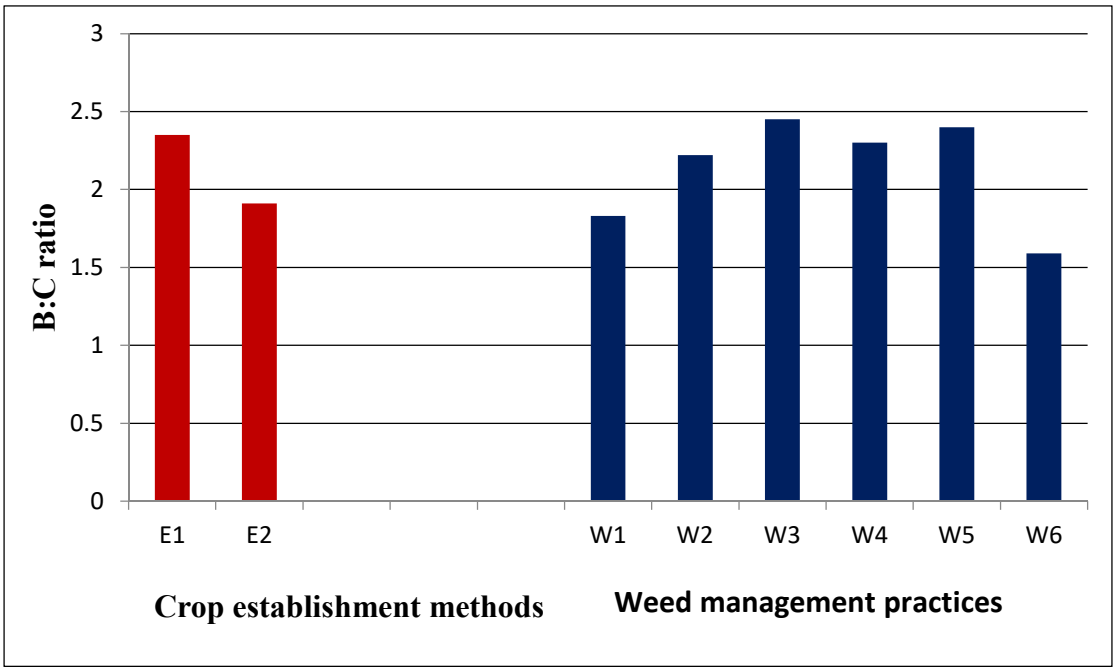


Figure 5.26. Interaction effect of crop establishment methods and weed management on B:C ratio

Summary

6. SUMMARY

The field experiment on "Crop establishment methods and weed management on productivity of cowpea [*Vigna unguiculata* (L.) Walp.]" was conducted with the objective of productivity enhancement of grain cowpea grown under different crop establishment methods through weed management. The experiment was laid out with factorial RBD with two factors.

Two crop establishment methods, broadcasting and line sowing and six weed management practices such as hand weeding @ 20 and 40 DAS, pre-mix of imazethapyr +imazamox, 40 g/ha @ 15-20 DAS, pre-mix of imazethapyr + imazamox, 40 g/ha @15- 20 DAS + hand weeding @ 40 DAS, imazethapyr, 40 g/ha @ 15- 20 DAS, imazethapyr, 40 g/ha @15- 20 DAS + hand weeding @ 40 DAS and unweeded control. The result of the experiment are summarized below

- Line sowing resulted in 39% reduction of total weed count compared with broadcasting.
- At 60 DAS lower weed count was noted in hand weeding and imazethapyr + imazamox, 40 g/ha @15- 20 DAS *fb* HW @ 40 DAS recorded 75.85 % reduction of weed count.
- Application of imazethapyr + imazamox, 40 g/ha @15- 20 DAS *fb* HW @ 40 DAS resulted in 80% and 76 % reduction of total weed count at 30 and 60 DAS.
- The lowest weed count at 30 DAS was observed in line sown hand weeded plot. However at 60 DAS imazethapyr + imazamox, 40 g/ha @15- 20 DAS *fb* HW @ 40 DAS in line sown crop recorded lower values of weed count.
- Line sowing recorded 31.2 % reduction in weed dry weight compared with broadcasting at 60 DAS.
- Both at 30 and 60 DAS hand weeding twice recorded the lowest weed dry weight.
- At 30 DAS hand weeding in line sown crop showed lower weed dry weight, but at 60 DAS hand weeding was equally effective in both line sown and broadcasted crops.
- WCE was higher in line sown plots at both stages of observation. Hand weeding

twice recorded high WCE at 30 DAS. At 60 DAS hand weeding twice, imazethapyr, 40 g/ha @ 15- 20 DAS and imazethapyr, 40 g/ha @15- 20 DAS *fb* HW @ 40 DAS showed high WCE of 87.38%, 87.02% and 87.07 %, respectively.

- Line sown crop showed low WI compared with broadcasted crop. Imazethapyr + imazamox, 40 g/ha @15- 20 DAS *fb* HW resulted in lower WI.
- Taller plants were observed in line sown treatments compared to broadcasting. Application of imazethapyr + mazamox, 40 g/ha @15- 20 DAS *fb* HW at 40 DAS resulted in taller plants, at 30 DAS.
- Higher LAI was noted in imazethapyr, 40 g/ha @15- 20 DAS *fb* HW at 40 DAS. At 60 DAS LAI was higher in imzethapyr, 40 g/ha @ 15- 20 DAS.
- Significantly higher 100 grain weight was noted in imazethapyr, 40 g/ha @15- 20 DAS *fb* HW at 40 DAS and minimum in weedy check.
- Significantly higher number of pods per plant and pod weight was observed in imazethapyr + mazamox, 40 g/ha @15- 20 DAS *fb* HW at 40 DAS. Number of seeds per pod was higher in hand weeding at 20 & 40 DAS and imazethapyr, 40 g/ha @15- 20 DAS *fb* HW at 40 DAS.
- Hand weeded treatment resulted in higher yield followed by imazethapyr + imazamox, 40 g/ha @15- 20 DAS coupled with HW @ 40 DAS.
- Adoption of weed management practices resulted in 69.9 % higher yield.
- Hand weeding twice in line sown crops resulted in 2.9 % higher yield compared with hand weeding twice in broadcasted field.
- Higher uptake of N and P_2O_5 was observed in imazethapyr, 40 g/ha @15- 20 DAS *fb* HW @ 40 DAS. However uptake of K was highest in imazethapyr + imazamox, 40 g/ha @15- 20 DAS *fb* HW @ 40 DAS.
- Weed management practices increased N, P_2O_5 and K_2O uptake of crop by 24.2%, 32.1% and 38.05% respectively compared with control.
- Higher availability of soil N was observed by the application of imazethapyr + imazamox, 40 g/ha @ 15-20 DAS followed by imazethapyr + imazamox, 40 g/ha @15- 20 DAS *fb* HW @ 40 DAS.
- Available P_2O_5 was highest in plots sprayed with imazethapyr + imazamox, 40 g/ha @15- 20 DAS *fb* HW @ 40 DAS.
- Spraying of imazethapyr + imazamox, 40 g/ha @15- 20 DAS *fb* HW @ 40 DAS

resulted in higher organic carbon and significantly lower oraganic carbon was observed in unweeded plot.

- The highest cost of cultivation, gross return but lower B:C ratio was registered in hand weeding @ 20 and 40 DAS. The highest B:C ratio was observed in imazethapyr + imazamox , 40 g/ha @ 15- 20 DAS *fb* HW @ 40 DAS.
- Adoption of weed management practices increased net return by 80%.
- Spraying of imazethapyr, 40 g/ha @ 15- 20 DAS and imazethapyr + imazamox, 40 g/ha @15-20 DAS ultimately led to 74 % and 73 % increase in net return.

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Appendices

Appendix 1-Monthly weather data during the experimental period (October 2020- December 2020)

Month-Year	Temperature		Mean relative humidity(%)	Wind speed (kmph)	Sunshine hours (Hrs.)	Mean monthly rainfall (mm)	Evaporation (mm)
	Maximum	Minimum					
October -2020	33.6	22.6	81	1.5	7.4	0.0	2.8
November-2020	33	22	70	4.4	6.6	1.9	3.6
December-2020	32	21.9	65	6.7	6.3	0.2	4.4

CROP ESTABLISHMENT METHODS AND WEED MANAGEMENT ON PRODUCTIVITY OF COWPEA [*Vigna unguiculata* (L.) Walp.]

BY

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ABSTRACT OF THE THESIS

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Abstract

Cowpea is an important pulse crop grown throughout India and Kerala as a grain and vegetable crop. Weeds possess severe problem in the early growth stages of cowpea due to wider spacing and low initial growth and resulted in yield reduction. Hence the crop requires to be kept weed free particularly during the initial 6-8 weeks, *ie* the critical period of competition. The present study was carried out with the objective to enhance the productivity of cowpea grown under different crop establishment methods by adopting proper weed management measures.

Field experiment was conducted from October to December 2020 at the Department of Agronomy, College of Agriculture, Vellanikkara. The experiment was laid out with factorial RBD with two factors replicated thrice. Factor A with two methods of establishments such as broadcasting and line sowing. Factor B with six weed management practices such as hand weeding @ 20 and 40 DAS , imazethapyr + imazamox, 40 g/ha @ 15-20 DAS , imazethapyr + imazamox, 40 g/ha @15- 20 DAS *fb* hand weeding @ 40 DAS, imazethapyr, 40 g/ha @ 15- 20 DAS, imazethapyr, 40 g/ha @15- 20 DAS *fb* hand weeding @ 40 DAS and unweeded control. Cowpea variety PGCP-6 was used as test crop.

Results revealed that methods of crop establishment had significant effect on weed density, growth parameters and yield attributes of cowpea. Line sowing resulted in 39% and 31% reduction in weed count and weed dry weight. Weed control efficiency and yield was 14% and 3% higher compared to broadcasting.

The lowest weed count, weed dry weight and higher weed control efficiency was recorded in hand weeding at 20 and 40 DAS. The lowest weed index was observed in imazethapyr + imazamox, 40 g/ha @15- 20 DAS *fb* hand weeding @ 40 DAS

Application of imazethapyr + imazamox, 40 g/ha @15- 20 DAS *fb* hand weeding at 40 DAS resulted in taller plants. At 30 DAS higher LAI was noted in imazethapyr, 40 g/ha @15- 20 DAS *fb* hand weeding @ 40 DAS. Imazethapyr, 40 g/ha @15- 20 DAS recorded higher LAI at 40 DAS.The highest dry matter production was recorded in imazethapyr, 40 g/ha @15- 20 DAS *fb* hand weeding @ 40 DAS.

Application of imazethapyr + imazamox, 40 g/ha @15- 20 DAS *fb* hand weeding imazethapyr, 40 g/h registered significantly higher number of pods per plant and pod weight. Number of seeds per pod and 100 grain weight was higher in imazethapyr, 40 g/ha @15- 20 DAS *fb* hand weeding @ 40 DAS. The highest yield was recorded from plots where two hand weeding were conducted (937.67 kg/ha), followed by imazethapyr + imazamox, 40 g/ha @15- 20 DAS *fb* hand weeding (877.30 kg/ha). Line sown cowpea received two hand weeding recorded higher yield (923.67 kg/ha) compared to other treatment combinations. Adoption of weed management practices resulted in 70 % higher yield in cowpea.

Nitrogen uptake by crop was higher in imazethapyr 40 g/ha @ 15- 20 DAS *fb* hand weeding @ 40 DAS, which was on par with hand weeding twice. Broadcasted plot, where two hand weeding were conducted recorded higher N uptake by crop. Higher P uptake was noticed in hand weeding @ 20 and 40 DAS. Higher soil N availability was observed in imazethapyr + imazamox 40 g/ha @ 15- 20 DAS and P availability was higher in imazethapyr + imazamox, 40 g/ha @ 15- 20 DAS *fb* hand weeding @ 40 DAS.

Among crop establishment methods higher net return and B:C ratio was observed in broadcast sowing compared with line sown cowpea. The highest net return (Rs. 102861) and B:C ratio (2.45) was registered in imazethapyr + imazamox @ 40 g/ha @ 15- 20 DAS *fb* hand weeding @ 40 DAS.

Results of the study indicated that application of imazethapyr + imazamox, 40 g/ha @ 15- 20 DAS *fb* hand weeding @ 40 DAS can be recommended as a cost effective weed management practice for broadcasted and line sown cowpea.

സംഗ്രഹം

കേരളത്തിലെ ഒരു പ്രധാന വിളയാണ് പയർ. കൃഷിയുടെ പ്രാരംഭഘട്ടത്തിൽ കളകൾ വളരുന്നത് ഉല്പാദനം കുറയാൻ ഇടയാക്കുന്നു.വിവിധ നടീൽ രീതികളിൽ വ്യത്യസ്ത കള നിയന്ത്രണ മാർഗ്ഗങ്ങൾ സ്വീകരിച്ചു ഉൽപ്പാദനം വർദ്ധിപ്പിക്കുക എന്ന ലക്ഷ്യത്തോടെയാണ് വെള്ളാനിക്കര കാർഷിക കോളേജിലെ അഗ്രോണോമി ഫാമിൽ 2020 ഒക്ടോബർ മുതൽ ഡിസംബർ വരെയുള്ള കാലയളവിൽ ഈ പരീക്ഷണം നടത്തിയത്.

. പയർ വിത്തുകൾ വിതക്കുകയും വരികളിൽ നടുകയും ചെയ്ത ശേഷം കള നിയന്ത്രണ മാർഗ്ഗങ്ങളായ വിതച്ചു 20,40 ദിവസങ്ങൾക്കു ശേഷം കൈ കൊണ്ട് കള പറിക്കുക(T1), വിതച്ചു 15-20 ദിവസങ്ങൾക്കു ശേഷം കളനാശിനികളായ ഈമാസത്തപൈറ്+ ഈമാസമോക്സ് പ്രയോഗിക്കുക(T2) ,വിതച്ചു 15-20 ദിവസങ്ങൾക്കു ശേഷം കളനാശിനികളായ ഈമാസത്തപൈറ്+ ഈമാസമോക്സ് പ്രയോഗിക്കുകയും 40 ദിവസങ്ങൾക്കു ശേഷം കളകൾ കൈ കൊണ്ട് പറിക്കുകയും ചെയ്യുക(T3) , വിതച്ചു 15-20 ദിവസങ്ങൾക്കു ശേഷം കളനാശിനിയായ ഈമാസത്തപൈറ് പ്രയോഗിക്കുക(T4),വിതച്ചു 15-20 ദിവസങ്ങൾക്കു ശേഷം കളനാശിനിയായ ഈമാസത്തപൈറ് പ്രയോഗിക്കുകയും 40 ദിവസങ്ങൾക്കു ശേഷം കളകൾ കൈ കൊണ്ട് പറിക്കുകയും ചെയ്യുക(T5), കള നിയന്ത്രണ മാർഗ്ഗങ്ങൾ അവലംബിക്കാതിരിക്കുക (T6) തുടങ്ങിയ രീതികളാണ് പരീക്ഷണ വിധേയമാക്കിയത്

കള നിയന്ത്രണ മാർഗ്ഗങ്ങൾ അവലംബിക്കുന്നത് കാരണം പയറു മണിയുടെ ഉൽപ്പാദനം 70% വർദ്ധിക്കുന്നതായി കണ്ടു . രണ്ടു പ്രാവശ്യം കൈ കൊണ്ട് കളകൾ പറിക്കുമ്പോഴും, ഈമാസത്തപൈറ്+ ഈമാസമോക്സ് പ്രയോഗിച്ചു 40 ദിവസങ്ങൾക്കു ശേഷം കളകൾ കൈ കൊണ്ട് പറിക്കുമ്പോഴും യഥാക്രമം 937.67kg/ha, 877.30 kg/ha എന്ന തോതിൽ പയർ ഉൽപ്പാദനം ലഭിക്കുകയുണ്ടായി. വിതക്കുന്നതിനെ അപേക്ഷിച്ചു വരികളിൽ നടുമ്പോഴാണ് കള നിയന്ത്രണം കൂടുതൽ സാധ്യമാകുന്നത്.എന്നാൽ തൊഴിൽ വേതനം കണക്കിലെടുക്കുമ്പോൾ വിത്ത് വിതക്കുന്ന രീതിയിലാണ് അറ്റാദായം കൂടുതൽ ലഭ്യമാകുന്നത്. വിത്ത് വിതക്കുമ്പോഴും വരികളിൽ നടുമ്പോഴും ഈമാസത്തപൈറ്+ ഈമാസമോക്സ് പ്രയോഗിക്കുകയും 40 ദിവസങ്ങൾക്കു ശേഷം കളകൾ പറിക്കുകയും ചെയ്ത രീതി കള നിയന്ത്രണത്തിനും നല്ല വിളവിനും അറ്റാദായത്തിനും ഏറ്റവും അനുയോജ്യമെന്ന് കണ്ടെത്തുകയുണ്ടായി