WEED MANAGEMENT IN SUMMER GROUNDNUT

(*Arachis hypogaea* L.)

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by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"WEED MANAGEMENT IN SUMMER GROUNDNUT (*Arachis hypogaea* L.)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"WEED MANAGEMENT IN SUMMER GROUNDNUT (*Arachis hypogaea* L.)"** is a record of research work done independently by Mr. Sarin, S. (2018-11-106) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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LIST OF ABBREVIATIONS AND SYMBOLS USED

%	Per cent
@	At the rate of
₹	Rupees
₹ ha^{-1}	Rupees per hectare
+	plus
AHAS	Acetohydroxy acid synthase enzyme
AICRPG	All-India Co-ordinated Research Project on Groundnut
ALS	Acetolactate synthase enzyme
B-C ratio	Benefit-cost ratio
BCR	Benefit-cost ratio
BLW	Broadleaved weed
$CaCO_3$	Calcium carbonate
CD (0.05)	Critical difference at 5 per cent level
cm	Centimetre
cm^2	Square centimetre
CO7	Coimbatore 7 (groundnut variety)
CPWC	Critical Period of Weed Control
CS	Capsule Suspension
DAS	Days after sowing
dicot	Dicotyledonous weeds
dS m^{-1}	Deci Siemens per meter
EC	Electrical conductivity
EC	Emulsifiable Concentrates
EPOE	Early Post-emergence
et al.	Co- workers/ co-authors
fb	Followed by
Fig.	Figure
FYM	Farmyard Manure
g	Gram
g ha^{-1}	Gram per hectare
GoI	Government of India
ha	Hectare
ha^{-1}	Per hectare
HW	Hand Weeding

IC	Inter-cultivation
ICGV	ICRISAT Groundnut Variety
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
IWM	Integrated Weed Management
K	Potassium
K_2O	Potassium oxide
KAU	Kerala Agriculture University
kg	Kilogram
kg ha^{-1}	Kilogram per hectare
L	Length of leaf
LA	Leaf Area
m^2	Square metre
MAS	Months After Sowing
mg kg^{-1}	Milligram per kilogram
Mg m^{-3}	Milligram per metre cube
mm	Millimetre
monocot	Monocotyledonous weeds
MSL	Mean Sea Level
N	Nitrogen
NS	Non-significant
$^{\circ}C$	Degree Celcius
P	Phosphorus
P_2O_5	Phosphorus pentoxide
PE	Pre-emergence
PoE	Post-emergence
R1	Replication 1
R2	Replication 2
R3	Replication 3
RBD	Randomized Block Design
RH	Relative Humidity
Rs.	Rupees
SEm	Standard Error of means
sp.	Species (singular)
spp.	Species (plural)
SSB	Stale Seed Bed
t ha^{-1}	Tonnes per hectare
TNAU	Tamil Nadu Agricultural University
viz.,	namely
W	Width of leaf
WAS	Weeks After Sowing

WCE	Weed Control Efficiency
WI	Weed Index

Introduction

1. INTRODUCTION

Groundnut, also known as peanut (*Arachis hypogaea* L.) is one among the main food, oil and forage crops of India. Globally India ranks second in the production of groundnut. Nambi *et al*. (2019) reported that 67 per cent of India's oil seed production and 59 per cent of edible oils is contributed by groundnut. According to GoI (2019), the area under groundnut cultivation in India is 5.02 million ha. Similarly, the production and productivity are assessed to be around 8.11 million tonnes and 1616 kg ha^{-1}, respectively. The edible oil demand is growing gradually. There has been a severe drop in the productivity as well as area of cultivation of groundnut. Hence to increase and stabilize the production of oilseeds, focused efforts are being made (Suseendra *et al*., 2019). Even as the world's market for groundnut is increasing, its cultivation level is still nominal, owing to many other problematic factors like organic matter depletion, pests and disease infestation and weed competition (Timsina *et al*., 2020).

Guggari *et al*. (1995) opined that weeds have fast germination and rapid growth which enable them to compete severely with the plant. Chaudhari *et al*. (2018) stated that weeds undesirably affect yield, quality and economic value as they compete for water, nutrients and light all through the growing season. They also reported a 60 to 80 per cent reduction in yield and decrease of harvesting efficiency in some cases due to the interference from combinations of grass and broadleaved weeds throughout the season.

The groundnut crop production is subject to various agronomic management practices and its modest productivity has numerous key rationales. Low productivity in groundnut is mainly due to the problem of weed infestation. Groundnut is mainly grown during the Kharif season. Monsoon creates a condition which is more congenial for the growth of weeds, and this in turn boosts recurrent flushes of different grasses and broad-leaved weeds during the whole season to compete with the crop, especially in its first 30 to 35 days of growth (Suseendra *et al*., 2019). Reduction in the yield of pod upto 17 to 84 per cent could be exerted due to the competitional stress of weeds (Shwetha *et al*., 2019).

The crop is extremely susceptible to weed competition than any other crop on account of the sluggish growth at early stages and also the petite growth and underground pod bearing habit. Sustainable yield losses in groundnut are caused more in the rainfed groundnut due to the diverse weed flora. Most of which are grassy weeds, broadleaved weeds and also sedges. Apart from competing with the crop, weeds also restrict peg formation, pod development and harvesting of the crop. Hence, weeds become the principal critical production factor for cultivation of groundnut and controlling weed population is a necessity to achieve optimal level of produce (Nambi *et al*., 2019).

Groundnut is an important summer oil seed crop and food grain legume of *Onattukara* region of Kerala which is spread over Alappuzha and Kollam districts. The sandy soils in this region, with its coarse texture and low water retention ability is congenial for groundnut peg penetration and development. In this context, weed management in groundnut will not only help to increase the yield and improve quality parameters but also will be a boon to increase income of the farmers. Since little work has been done in the above aspects in these tracts of Kerala, the current experiment was conducted by taking the objectives mentioned below into consideration.

- To find out the best weed management option for summer groundnut in the *Onattukara* tract
- To work out the economics of cultivation

Review of Literature

2. REVIEW OF LITERATURE

An investigation entitled "Weed management in summer groundnut (*Arachis hypogaea* L.)" was undertaken for the duration of 2 years from 2018-2020 to find out the best weed management strategy for summer groundnut in the *Onattukara* tract and compute the economics of production. Studies on management of weeds in groundnut were reviewed and presented in this chapter.

Groundnut commonly referred to as 'the king of oilseeds' is one among the cardinal leguminous oilseed crops of our country. Among various biotic stresses resulting in low productivity of groundnut, weeds are considered as a major constraint, especially under rainfed ecosystems. As per ballpark figures, losses in peanut cultivation in India by virtue of weed competition, ranges from thirty-three to seventy per cent (Prasanna *et al*., 2015).

2.1. WEED FLORA IN GROUNDNUT

The weed flora of groundnut comprised of diverse plant species ranging from grasses to broadleaved weeds and sedges and cause severe yield reduction (15 to 75 per cent) which are more in bunch type than in virginia groundnut (Priya *et al.*, 2013). Sharma *et al*. (2015) found that major monocot weeds in groundnut were *Cynodon dactylon* (L.) and *Aeluropus villosus* (L), the predominant broadleaved weeds were *Digeria arvensis* and *Euphorbia hirta* and the only sedge observed in the field during the cropping period was *Cyperus rotundus*. Bhagyasree *et al*. (2018) identified the weed flora in Kharif groundnut + pigeonpea intercropping system. The main monocot weeds were *Cynodon dactylon, Digitaria marginata, Erogrostis gangetica, Dactyloctenium aegyptium* and *Panicum spp*. The most common dicot weeds observed were *Amaranthus viridis, Tribulus terrestris, Digeria arvensis, Euphorbia hirta*, *Parthenium hysterophorus*, *Lagasca mollis, Abutilon indicum, Leucus aspera, Mimosa pudica, Portulaca oleracea, Tridax procumbens, Phyllanthus niruri* and *Trichodesma spp*. Sedges were absent in the system. Divyamani *et al*. (2018) observed that the most dominating weed species associated with groundnut was *Cyperus rotundus* (52 %) followed by *Digitaria sanguinalis* (10 %).

The major weed species associated with rabi groundnut were *Cyperus rotundus*, *Boerhavia erecta*, *Commelina bengalensis*, *Celosia argentea*, *Cleome viscosa*, *Dactyloctenium aegyptium*, *Phyllanthus niruri* and *Trichodesma indicum* (Kumar *et al*., 2019). Nambi *et al.* (2019) found that the major category of weeds in peanut was broadleaved weeds (BLW) in kharif. Those following BLW were grassy weeds and sedges. Total number of weed species identified were fifteen, out of which *Cynodon dactylon, Dactyloctenium aegyptium, Panicum repens, Echinochola colonum* were the major weeds among the grasses, *Cleome gynandra, Cleome viscosa, Phyllanthus niruri, Boerhaavia diffusa and Eclipta alba* among the broadleaved weeds and *Cyperus rotundus* among sedges.

Shweta *et al.* (2019) mentioned that floral composition of weeds observed in kharif groundnut encompassed of grasses, sedges and broadleaved weeds. They also observed that grasses and broadleaved weeds dominated during the incipient years, with grassy weeds dominating the first year of cultivation and broadleaved weeds dominating the second. The predominant species of weeds that influenced the performance of crop included *Tridax* sp., *Leptocloa* sp. *and Mulugo* sp.

2.2. CROP WEED COMPETITION

The critical period for weed control (CPWC) is a key component of an integrated weed management (IWM) program (Knezevic, 2002). Zimdhal (2004) revealed that with an increase in the time of intrusion effect of the weeds and the different types of weed species involved, there was a reduction in yield of peanut. For escalating yield and net returns in groundnut, the process of elimination of weeds during the initial (15, 30 and 45 DAS) and later growth stages *viz*., 60 DAS, is of substantial importance (Nambi and Sundari, 2008). Wesley *et al.* (2008) expressed that the time of critical crop-grassy weed competition was in the second month of the crop, while that of BLW were from 2 WAS to 2 MAS. The period of critical weed competition for groundnut cultivation in summer in the alluvial valleys along the sides of the Ganges near West Bengal was studied, which led to the revelation that it was mandatory to control weeds from two to seven weeks after emergence to avoid losses above five per cent (Majumder, 2009).

Jat *et al*. (2011) stated that the first one to two months after sowing was identified as the period of critical weed control. They also opined that the huge losses could be attributed to reasons like the lethargic growth habit during the early days coupled with the immense weed competition towards the later stages. Gharde *et al*. (2018) commented that the space that is not occupied by the crop is easily covered by weeds which eventuated curbed yields. Kumari *et al.* (2020) revealed that growth attributes of groundnut were the lowest with untreated control throughout the growing period due to severe weed infestation alongwith crop weed interference.

2.3. WEED MANAGEMENT PRACTICES

Weed management methods include physical, cultural, biological and chemical methods. Amongst these methods, each one has more suitability than the others, for their usage under specific cases of crop, time and location. Chemical method of weed control rather fast, more effectual, time-saving and labour-effective method (Ahmad *et al*., 2004). Cultural methods are labour intensive, time-killing and getting more and more expensive nowadays, as it is practically close to being impossible and uneconomical to refrain from the use of any modern weed control practices (Nadeem *et al*., 2008).

2.3.1. Physical and cultural methods

Weed control by physical and cultural methods have some limitations as they are laborious, time consuming and expensive. Dhakar *et al.* (2000) stated that the top-most yield (1717 kg per ha), net income (Rs. 11017 per ha) and BCR (1.23) for groundnut cultivation in kharif season were obtained as a result of adoption of physical weed control measures mainly manual hoeing given twice, one at 20 DAS and subsequently, one at 40 DAS.

Jat *et al.* (2011) commented on the importance of hand weeding given initially around 20 to 25 DAS and afterward repeated at every 12 to 15 days for a period of 50 to 55 days for effective control of weeds. Implements *viz.* star weeder and various hoe that are operated manually are useful in carrying out intercultural operations and have better economic value when compared with hand weeding.

Kumar *et al*. (2019) reported that taller plants were produced as a result of manual weeding done two times, one at 20 DAS and another at 40 DAS. Well maintained weed less environment and improved soil physical state could have been the probable reasons for this. This in turn might have increased the internodal length. Manual weeding was comparable with pendimethalin applied serially with cycloxydim @ 100 g ha^{-1} applied 3 weeks after sowing.

Nambi *et al*. (2019) mentioned the fact that hand weeding given twice after two weeks and also after four weeks from the date of sowing recorded the lowest weed index. The stale seed bed technique is a cultural practice that shows great potential as a viable component of an integrated weed management programme for conventional and organic crop production, could improve weed control while lowering herbicide applications and overall production cost (Senthilkumar *et al.*, 2019). Hand weeding done twice and one inter cultivation treatments have documented more significant yield (2.24 t ha^{-1}) which was comparable with pendimethalin (PE) and imazethapyr or quizalofop-ethyl or propaquizafop applied as post-emergence (Shwetha *et al*., 2019).

2.3.2. Chemical method

Chemical means of management of weeds while being one among the effective methods, on continuous usage, leads to residue threats, weed shift and herbicide resistance. Some novel herbicides appropriate for groundnut has been developed with the aim of minimizing the losses caused by weeds (Nambi *et al*., 2019).

Price and Wilcut (2002) ascertained that diclosulam @ 27 g ha^{-1} was very much competent in controlling yellow nutsedge population to the tune of 65 to 100 per cent, when applied unaided or along with dimethenamide. In the management of many annual grasses and small seeded broadleaved weeds, certain herbicides especially dinitroanilines, like ethalfluralin, trifluralin or pendimethalin are applied as pre plant incorporation (Grichar and Dotray, 2012). Sangeetha *et al.* (2012) commented that application of weedicides like quizalofop-ethyl and propaquizafop were only effective in the control of grassy weeds. Imazethapyr (PoE) recorded remarkably lower density of weeds and remained statistically at par with quizalofop-ethyl and propaquizafop at 15, 30 and 45 days after herbicide application.

For control of weeds in groundnut, application of imazethapyr has longer longevity in soil and plant and has a half-life of 33 months and hence the options of subsequent crops is restricted. It is also ineffective against grasses (Sondhia *et al*., 2015). The common pre-emergence herbicides in groundnut were diclosulam, *S*-metolachlor, flumioxazin, and sulfentrazone (Jordan, 2016).

Aruna and Sagar (2018) detailed that quizalofop-ethyl was effective in controlling grasses and sedges in dicot crops. Among pre-emergence weedicides, pendimethalin is selective in nature and belongs to dinitroaniline group as well as alachlor from the chloroacetanilide family were the ones most commonly used for weed control in groundnut (Ashwin *et al*., 2018). Chaudhari *et al.* (2018) found that *Amaranthus palmeri* is a weed that escapes weed management programs in the initial part of the year or when it emerges far ahead in the crop season. The weed management was done by subsequent application of early post-emergence or post-emergence weedicides following preplant incorporation or pre-emergence weedicides.

Kumar *et al*. (2019) stated that employing 20 g ha^{-1} of diclosulam as pre-emergence controlled all the classes of weeds in an exceptionally effective manner in contrast with pre-emergence application of both the formulations (CS and EC) of pendimethalin.

In a study on kharif groundnut, the assessment of herbicides which were post-emergent in nature revealed that imazethapyr and chlorimuron ethyl recorded significantly lower broadleaved weeds density at 15, 30 and 45 days after application of herbicides. In case of grassy weeds, lower weed density was recorded with quizalofop-ethyl which was at par with propaquizafop followed by imazethapyr. The results indicated that imazethapyr was effective in controlling both broadleaved and grassy weeds (Shwetha *et al*., 2019).

Suseendra *et al.* (2019) stated that herbicide application decreases the weed flora, very early in the growing period of the crop. This paved the way, in the course of time, for improved crop growth, pegging and development at critical growth stages of groundnut which ultimately led to improvement in yield attributes.

2.3.3. Integrated Weed Management (IWM)

Numerous methods are being taken up to manage weeds. Cultural and mechanical methods are laborious, uneconomical and takes lot of time. While the use of bio-control is not a practical option in field crops because there occurs the issue of complexity of weed (Thimmegowda *et al.*, 2007). In groundnut, selectivity in weed control was shown by some herbicides. However, in order to attain efficient and profitable weed control it is advisable to go for sequential application of herbicides or combinations of herbicides along with other methods of weed control. Such combining of chemical, cultural and mechanical weed management methods has proven to provide enhanced weed control efficiency and financial benefits than the use of any individual method (Jat *et al*., 2011).

Mathukia *et al.* (2017) studied the weed control aspects in organically cultivated groundnut and his results revealed that stale seed bed, among the different treatments, stood out as a competent measure in lowering the weed biomass to the lowest possible and pod and haulm yields to the highest.

According to the study conducted by Mavarkar *et al*. (2017) the integration of physical, cultural and chemical means had striking impacts on the yield attributes and economics of cultivation in groundnut, as compared to unweeded crop.

According to AICRPG (2009), pendimethalin (PE) + quizalofop ethyl (PoE), along with a hand weeding given 45 days after the date of sowing proved efficient at parts of states of central and south India like Gujarat, Maharashtra, Karnataka and Andhra Pradesh. Application of pendimethalin as pre-emergence + imazethapyr (PoE) @ 75 g per ha applied 3 weeks after sowing coupled with manual weeding by hand at 45 DAS was found superior in the states of Maharashtra, Tamil Nadu and Rajasthan. Pendimethalin @ 1 kg per ha applied as pre-emergence followed by manual weeding by hand at 45 DAS documented the least density of both monocot and broadleaved weeds in Telangana.

Olayinka and Etejere (2015) ascertained that in order to have an enhancement in the growth and yield, the better agronomic practice was to hand weed the crop 6 weeks from the date of sowing preceded by mulching with 10 cm deep rice straw in groundnut.

The positive effects that weed control exerted on physiological characters *viz*., leaf area development, dry weight accumulation, relative rate of growth, net rate of assimilation and crop growth rate could be the reason for this enhanced growth and yield.

For effective weed control, the use of selective herbicides as pre-emergence alone does not serve the purpose. It offers control of weeds only at initial stages and every interval requires integration with one manual weeding. Two hand weed removal + intercultivation documented significant low value of weed population per square metre, weed biomass and better weed control efficiency and was coupled with pendimethalin (PE) along with one intercultivation (Shwetha *et al*., 2019). In an investigation out by Nambi *et al*. (2019), it was found that pendimethalin (PE) @ 1 kg ha^{-1} plus a single hand weeding was recognised as the superior treatment among the various herbicides and cultural practices adopted, in reducing weed biomass. Pendimethalin (PE) @ 1 kg ha^{-1} + 1 HW given one month from the date of sowing enumerated maximum weed control index. Hand weeding done twice, one at 15 DAS and another at 30 DAS documented the next better weed control option.

2.4. EFFECT OF WEED MANAGEMENT ON WEED POPULATION, WEED CONTROL EFFICIENCY AND WEED INDEX

According to Patel *et al.* (2008), during situations of labour shortage in the cultivation of groundnut in summer, pendimethalin application (PE) @ 1 kilogram per ha^{-1} accompanied with one inter culturing at 25 DAS was able to record lower biomass of weeds and higher WCE. The same treatment (pendimethalin) also registered less number of weeds, elevated pod and haulm yields. This was attributed to the weed control effected at early stages of growth (Bhatt *et al.*, 2008). In groundnut cultivation, hand weeding given twice, one each at 3 WAS and 6 WAS and manual removal of weeds at 8 WAS displayed exceptional efficiency in recording the lowest weed population per square metre, weed dry matter, weed index and the highest weed control efficiency and were thereby identified as the better practices in controlling weeds. The highest growth and yield parameters were also manifested by the above-mentioned treatment in groundnut (Kalhapure *et al.,* 2013). Imazethapyr + pendamethalin 800 g followed by its higher doses were recognized as the effectual practice in minimising the population per m^2 and biomass of broadleaved and grassy weeds in groundnut. This could be the result of wide-ranging activity of combination weedicides on growth and development in particular, of both broadleaved weeds and grasses. These chemicals are superior in their capability in impeding the meristematic cell division by virtue of swift drying of weeds (Singh *et al*., 2017). Kumar *et al*. (2019) specified that minimum population per m^2 and dry weight of weeds were recorded when diclosulam (PE) was applied @ 20 g ha^{-1} accompanied by hand weeding at flowering stage. All the other treatments were significantly inferior to it with regard to weed density and remained statistically at par with diclosulam (PE) @ 20 g ha^{-1} + cycloxydim @ 100 g ha^{-1} with respect to dry weight of weeds.

2.5. EFFECT OF WEED MANAGEMENT ON GROWTH ATTRIBUTES OF GROUNDNUT

In groundnut, remarkable yield reduction was eventuated owing to its diminished crop canopy during the initial one and a half month of growth as it aids severe crop-weed competition (Shanwad *et al*., 2011). Pendimethalin (PE) @ 0.9 kg ha^{-1} + imazethapyr @ 75 g ha^{-1} at 20 DAS and the treatment where hand weeding (HW) and inter culturing (IC) repeated at 20 and 40 DAS, had practically similar influence on plant height, number of branches per plant, dry matter accumulation and leaf chlorophyll content of the plant and were comparable statistically with weed free plot. Pendimethalin (PE) *fb* HW and IC one-time at flowering stage and HW plus IC repeated at 20 and 40 DAS were also at par in their effect on plant height and biomass towards terminal stages of growth *viz.*, 60 DAS and harvest (Sharma *et al*., 2015).

Choudhary *et al.* (2017) stated that significantly greater values for growth characters *viz.*, height of plant, dry matter content at 60 and 90 DAS and at end of crop period and also total nodule number per plant at pegging stage were registered in the weed free treatment. Bhagyasree *et al.* (2018) mentioned that, towards the later stages, weed free treatment recorded the presence of significantly taller plants. Among chemical treatments, more height was noted with spraying of pendimethalin (PE) @ 750 g ha^{-1} *fb* imazethapyr + imazamox (PoE) @ 70 g ha^{-1} applied 3 WAS plus an inter cultivation at 6 WAS. At 60 DAS, significantly more leaf area per plant was registered under weed free check. However, it was comparable with pendimethalin (PE) @ 750 g ha^{-1} followed up by the combination of imazethapyr + imazamox (at 20 DAS) @ 70 g ha^{-1} combined with an intercultivation at 45 DAS and also with pendimethalin (PE) + imazethapyr (PoE) at 20 DAS @ 75 g ha^{-1} + intercultivation done at flowering stage of crop.

Ashwin *et al*. (2018) commented that manual weeding treatments recorded more nodules per plant. Less nodules per plant were noted in the plots of pendimethalin treatment. Kumar *et al.* (2019) investigated the herbicidal effect on groundnut and reported that hand weeding given two times at 20 and 40 DAS led to the production of taller plants. It was statistically comparable with sequential spraying of pendimethalin + cycloxydim (at 20 DAS) @ 100 g ha^{-1}. In another work, pendimethalin application as pre-emergent spray @ 1 kilogram per ha together with 1 manual weeding by hand at 30 DAS documented maximum plant height and the next best treatment in terms of height of crop was hand weeding twice, one at 15 and another at 30 DAS (Nambi *et al.*, 2019).

2.6. EFFECT OF WEED MANAGEMENT ON YIELD ATTRIBUTES AND YIELD OF GROUNDNUT

In addition to the competition for nutrients, soil moisture and sunlight, weeds in groundnut also hinder peg formation and penetration, development of pods and also interfere with harvest and other operations. Sharma *et al*. (2015) found that, among the various measures adopted for the control of weeds, more number of pegs and pods, 100 seed weight, haulm yield and shelling percentage were recorded in hand weeding + interculturing at 20, 40 days after sowing. They also found that it was statistically comparable with pendimethalin (PE) @ 0.9 kg ha^{-1} followed up with HW and IC at flowering. Amidst the various treatments employed for control of weeds in groundnut, weed-free plot, recommended cultural practice and imazethapyr @ 100 g per ha had a pronounced affirmative impact on the yield attributes, yield and net returns as compared to unweeded crop (Mavarkar *et al.*, 2017).

Weed-free treatment enumerated remarkably higher pod (1768 kg per unit area), haulm (2606 kg per unit area) and biological yield (4374 kg per unit area) and statistically stayed at par with hand weeding given once at 20 and once at 45 DAS, pendimethalin (PE) @ 0.9 kg ha^{-1} and oxyfluorfen (PE) @ 0.24 kg ha^{-1} *fb* imazethapyr (PoE) @ 0.07 kg ha^{-1} at 20 DAS + manual weeding by hand given at 45 DAS (Choudhary *et al.*, 2017). Divyamani *et al*. (2018) documented that, betwixt the various practices tested for control of weeds, two manual weedings by hand at 3 and 6 WAS recorded the highest pod yield, kernel yield and gross returns. It was statistically comparable with pendimethalin (PE) accompanied with one hand weeding given at 20 DAS and imazethapyr + quizalofop-p-ethyl applied as post-emergence.

Aruna and Sagar (2018) reported that weed free plot registered considerably larger number of pods and total pod weight and was statistically comparable with two hand weedings, one at early stage and another at 40 DAS and also to pendimethalin (PE) @ 1.5 kg ha^{-1} coupled with application of imazethapyr as post-emergence (at 20 to 30 DAS) @ 75 g ha^{-1}. Bhagyasree *et al*. (2018) ascertained that weed free treatment registered (1790 kg per ha) significantly higher pod yield (133 per cent higher than unweeded check). Among the chemical management options, the pendimethalin (PE) application @ 750 g ha^{-1} succeeded with the imazethapyr + imazamox application (PoE)

@ 70 g ha^{-1} (at 20 to 25 DAS) documented remarkably superior pod yield to the tune of more than 100 per cent more over the weedy check.

Kumar *et al*. (2019) reported that the best treatment in terms of pod yield (2.10 t ha^{-1}) and haulm yield (3.05 t ha^{-1}) was application of diclosulam (PE) @ 20 g ha^{-1} augmented with manual hand weeding applied at flowering stage in rabi groundnut. The decline in pod and haulm yield of groundnut in unweeded check plots were 48.8 and 36.1 per cent, respectively.

The distinct reduction in weed dry matter under pendimethalin application as pre-emergence accompanied with a hand weeding on 30 DAS might have offered a weed free environment for groundnut which enumerated more pods per plant and shelling percentage (Nambi *et al*., 2019). Suseendra *et al*. (2019) mentioned that weeding by hand recorded significantly higher pod yield of 2645 kg per unit area (61.73 per cent higher than control). The yield of hand weeding was comparable with pendimethalin (PE) application @ 1 kg per ha *fb* sodium acifluorfen + clodinofop propergyl as early post-emergent application @ 900 g ha^{-1}.

2.7. EFFECT OF WEED MANAGEMENT ON NUTRIENT UPTAKE AND SOIL NUTRIENT STATUS

Sudharshana (2012) reported that the physical, physicochemical and fertility properties of soil were not skeptically affected by the application of weedicides like imazethapyr and pendimethalin at the recommended and double the recommended doses. Choudhary *et al*. (2017) stated that under the treatment that created a weed-less environment, the primary nutrient uptake was significantly greater, which was statistically comparable with weeding by hand at 20 and 45 DAS and oxyfluorfen (PE) @ 0.24 kg ha^{-1} *fb* imazethapyr (PoE) + weeding by hand at 45 DAS. Among different weed control practices, twice hand weeding documented the highest nitrogen, phosphorus and potassium uptake. It was on par with pendimethalin (PE) *fb* weeding by hand at 20 DAS and also with imazethapyr + quizalofop-p-ethyl as post-emergence application (Divyamani *et al.*, 2018).

2.8. EFFECT OF WEED MANAGEMENT ON ECONOMICS

Sasikala *et al.* (2004) reported that maximum net returns were obtained with imazethapyr (PoE) following the pre-plant incorporation of fluchloralin. Top-most gross returns enumeration was from weed free plot (Rs. 158925 per ha). The second highest gross income was generated by manual weeding repeated at 20 and 40 DAS (Rs. 157050 per ha) followed by pendimethalin (PE) + imazethapyr (PoE) at 18 to 20 DAS (Rs. 146737 per ha). The least gross returns were obtained in unweeded check. Rao *et al.* (2011) stated that treatment of herbicides (both pre-emergence and post-emergence) recorded escalated net income and B-C ratio in groundnut. Kalhapure *et al*. **(**2013) found that weed free control recorded the highest gross monetary value (Rs. 109845 ha^{-1}) in integrated weed management programme. Their studies revealed that pre-emergence application of pendimethalin 1.5 kg ha^{-1} + imazethapyr 0.15 kg ha^{-1} as post-emergence + one hand weeding at 40 DAS, enumerated a net income of Rs. 61460 ha^{-1} and a B-C ratio of 2.42 which was identified to be the highest among the treatments and was the best practically feasible and capital-saving practice for weed control in groundnut.

Weed free check tallied considerably high gross returns in comparison to other treatments (Rs. 87851 per ha) in groundnut. It was closely followed by alachlor (PE) @ 1.5 kg per ha + two intercultivation at 25 and 40 DAS *fb* one hand weeding at 40 to 45 DAS (Chapparaband, 2011). Sharma *et al*. (2015) documented that the net returns were the highest in pendimethalin (PE) @ 0.9 kg ha^{-1} + imazethapyr (PoE) @ 75 g ha^{-1} at 20 DAS. The same treatment also registered the highest B-C ratio (2.56), closely followed by pendimethalin (PE) + HW and intercultivation at 40 DAS.

The cost-profit analysis of the various weed management measures by Poonia *et al*. (2016) disclosed the fact that after weed free check, the net income was the highest (Rs. 40657 per ha) in pendimethalin (PE) @ 0.9 kg ha^{-1} added with HW at flowering stage. Higher benefit cost ratio (2.38) enumeration was obtained under pre-emergent spray of pendimethalin @ 0.9 kg ha^{-1} combined with HW and intercultivation at 45 DAS. The lowest benefit-cost ratio (2.14) was documented under weed free check owing to its higher cultivation cost arising as a result of higher labour wages involved. Divyamani *et al*. (2018) stated that highest gross income was generated by giving two manual weedings by hand, one at 20 DAS and another at 40 DAS.

Kausar *et al.* (2019) opined that application of recommended doses of pre-emergence herbicides like pendimethalin and trifluralin were the best suited and cost-effective practice for the control of weeds in groundnut. They concluded that hoeing by hand paved the way for considerable yield in groundnut, however it proved to be an uneconomical practice due to high wages accrued on labour.

Among the treatments, diclosulam when applied as pre-emergent spray *fb* HW at 40 DAS produced significantly high net returns and BCR. It was higher than pre-emergent spraying of diclosulam @ 20 g ha^{-1} *fb* cycloxydim @ 100 g ha^{-1} at 20 DAS (Kumar *et al*., 2019). Shweta *et al*. (2019) specified that pendimethalin (PE) documented remarkably higher net income (Rs. 49707 per ha) and BCR (2.53). It was closely followed by application of imazethapyr (PoE) which recorded a net income of Rs. 43474 per ha and a BCR of 2.32. Quizalofop-ethyl and propaquizafop treatments were comparable with imazethapyr treatment in terms of net returns and BCR.

Vora *et al*. (2019) stated that the highest net income was generated under weed free treatment. Yet, quizalofop-ethyl @ 40 g ha^{-1} applied at 20 DAS supplemented with one manual weeding and inter-cultivation at 40 DAS recorded the highest B-C ratio (3.29).

Materials and Methods

3. MATERIALS AND METHODS

A field investigation on “Weed management in summer groundnut (*Arachis hypogaea* L.)” was undertaken during 2018-20 to evaluate the effect of weed management strategies on growth and yield of groundnut in the summer rice fallows of *Onattukara* and to work out the economics of cultivation. The experiment was carried out from December 2019 to April 2020 in farmer’s field at Vallikunnam Panchayath in the *Onattukara* region of Alappuzha district. The technicalities regarding the materials and methods used in the experiment are described below in a brief manner.

3.1 EXPERIMENTAL SITE

3.1.1 Location

The lay out of the experiment was done in summer rice fallow of *Onattukara* region of Alappuzha during the period from December 2019 to April 2020. The location of the field is 9° 7' 32.052" N latitude and 76° 34' 26.85" E longitude. The field is at an altitude of 3 metres above MSL.

3.1.2 Soil

The experimental site consists of sandy loam soil which belongs to the soil order Entisol. The details regarding the physico-chemical properties of soil are given in Tables 1a. and 1b.

3.1.3. Cropping History

During the previous season, rice was cultivated in this experimental site.

3.1.4. Season

Table. 1a. Physical properties of soil before the experiment.

MECHANICAL COMPOSITION		
Particulars	**Value (%)**	**Method adopted**
Coarse sand	67.85	Bouyoucos hydrometer method (Bouyoucos, 1962)
Fine sand	17.80	
Silt	5.01	
Clay	9.34	
SOIL PHYSICAL CHARACTERISTICS		
Particulars	**Soil depth (0-30 cm)**	**Method adopted**
Particle density (Mg m^{-3})	2.38	Pycnometer method (Black, 1965)
Bulk density (Mg m^{-3})	1.55	Core method (Gupta and Dakshinamoorthi, 1980)
Porosity (%)	25.23	

Table. 1b. Chemical properties of soil before the experiment.

SOIL CHEMICAL PROPERTIES		
Parameter	**Content**	**Method adopted**
Soil pH	5.33 (Strongly acidic)	Soil water suspension of 1:2.5 and read in pH meter (Jackson, 1973)
EC ($dS\ m^{-1}$)	0.05 (Normal)	Conductivity meter (1:2.5 soil water ratio) (Jackson, 1973)
Organic Carbon (%)	1.02 (Medium)	Walkley and Black rapid titration method (Walkley and Black, 1934)
Available N ($kg\ ha^{-1}$)	225.79 (Low)	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P ($kg\ ha^{-1}$)	19.43 (Medium)	Brays colorimetric method (Jackson, 1973)
Available K ($kg\ ha^{-1}$)	201.6 (Medium)	Ammonium acetate extract (Jackson, 1973)

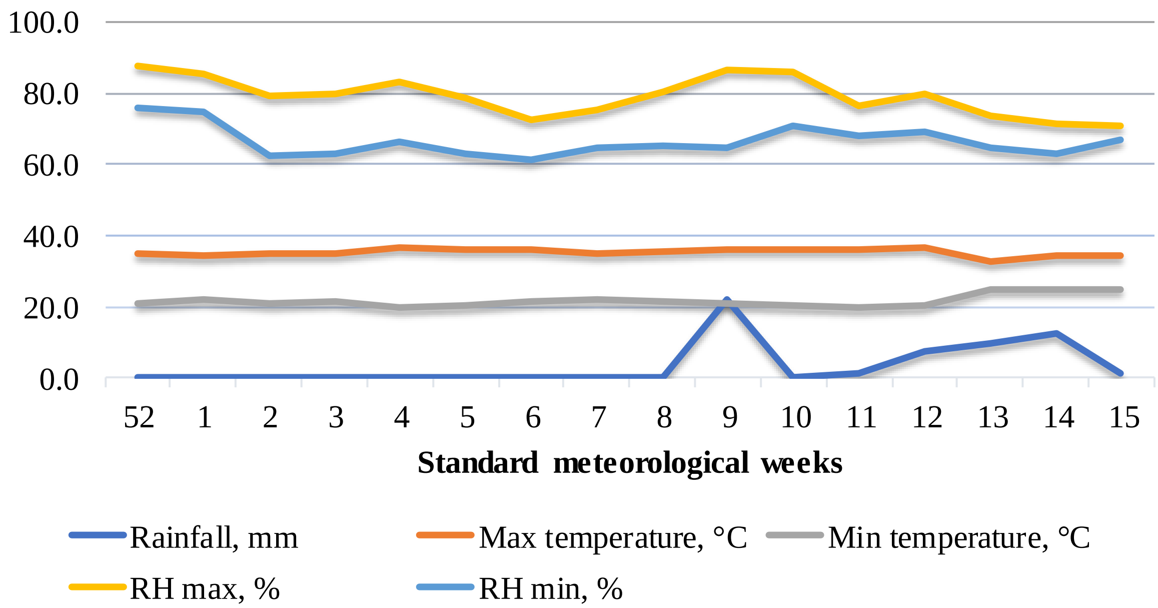

Fig. 1. Weather data during the crop period (December 2019 to April 2020)

The study was carried out in summer rice fallow after the harvest of first crop from December 2019 to April 2020.

3.1.5. Weather Conditions

Weather data during the crop period is presented in Fig.1. A mean rainfall of 3.4 mm was received during the growing season. The mean maximum temperature recorded was 35.3 ^{o}C and minimum temperature of the period was 21.7 ^{o}C. Relative humidity was in the range from 61.6 to 87.6 per cent.

3.2. MATERIALS

3.2.1. Seed Material

The variety used in the study was CO7. It was developed at ICRISAT and released for cultivation as CO7 in Tamil Nadu. CO7 is a Spanish bunch groundnut culture ICGV 0351 (a cross derivative of ICGV 87290 X ICGV 87846), high yielding in nature. The seeds were obtained from the Department of Oilseeds, Centre of Plant Breeding and Genetics, TNAU, Coimbatore.

3.2.2. Manures and Fertilisers

Locally available farmyard manure (0.4% N, 0.3% P_20_5 and 0.2% K_2O) was used for the work. Urea (46% N), Rajphos (20% P_2O_5), MOP (60% K_2O) and lime ($CaCO_3$) were used for the experiment.

3.3 METHODS

3.3.1. Experimental Design and Layout

The design used for the experiment was Randomised Block Design (RBD) with 9 treatments and 3 replications. Fig. 2 shows the layout plan of the experiment. The details of the layout are as follows:

Design : RBD

Treatment : 9

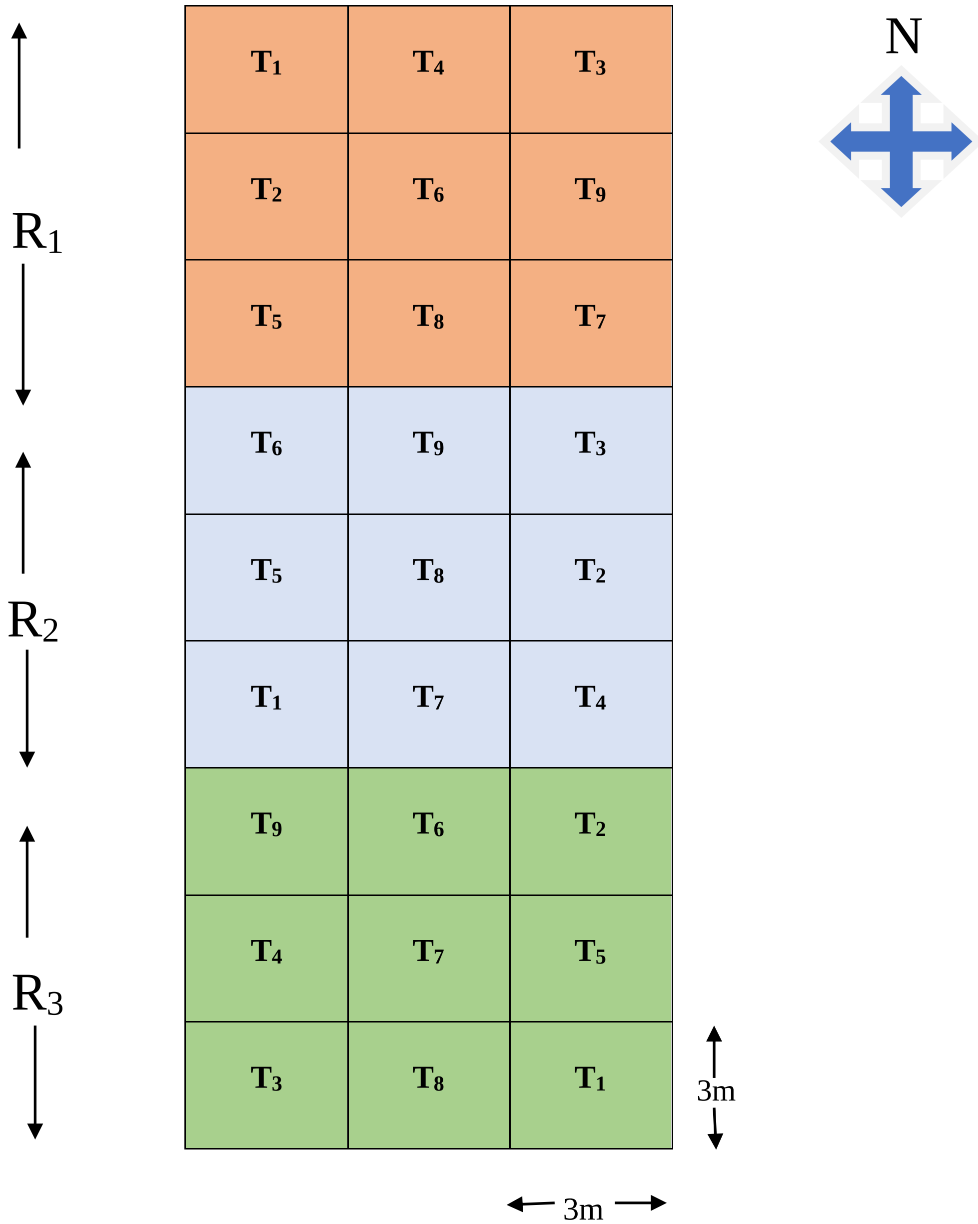

Fig. 2. Layout of the experiment

Replication : 3

Plot size : 3 m x 3 m

Spacing : 15 cm x 15 cm

Seed rate : 100 kg kernels ha^{-1}

3.3.2. Treatments

T_1: Stale seed bed + 1 hand weeding at 30 DAS

T_2: Imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS

T_3: Imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS

T_4: Imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS

T_5: Imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS

T_6: Pendimethalin (PE) @ 1.0 kg ha^{-1}

T_7: Pendimethalin (PE) @ 1.0 kg ha^{-1} + 1 hand weeding at 30 DAS

T_8: Hand weeding at 20 DAS and 45 DAS

T_9: Unweeded check

*As per package of practices of KAU (2016), FYM @ 2 t ha^{-1} and N: P_2O_5: K_2O @ 10:75:75 kg ha^{-1} as basal and lime @ 1.5 t ha^{-1} were applied uniformly to all treatments.

3.3.3 Cultivation Practices

3.3.3.1. Field Preparation

The plot was ploughed two times using a power tiller. After removal of stubbles and levelling, the treatment plots were laid out with dimensions of 3 m x 3 m. For SSB, the land was prepared to fine tilth and a pre-sowing irrigation was given in order to germinate the viable weed seeds in the seedbed and left undisturbed for 14 days. The germinated weeds were removed by slight raking of soil.

3.3.3.2 Application of Manures, Fertilizers and Lime

Plate 1. General view of experimental field

Basal application of farmyard manure @ 2 t ha^{-1} was given to all plots uniformly. Recommended dosage of fertilisers were provided @ 10: 75: 75 kg ha^{-1} of N: P_2O_5: K_2O in the form of urea (46 % N), rajphos (20 % P_2O_5) and MOP (60 % K_2O), as basal to all plots in a uniform manner. Lime was applied @ 1.5 t ha^{-1} at flowering stage.

3.3.3.3. Seeds and Sowing

The pods of groundnut variety CO7 were shelled by hand carefully and kernels were dibbled at a spacing of 15 cm x 15 cm @ 100 kg ha^{-1} in such a way that the sown seeds were only covered by a shallow depth of soil. The date of sowing was 25th December, 2019.

3.3.3.4. Gap Filling

It was done one week after planting to maintain optimum plant population.

3.3.3.5. Irrigation

The field was irrigated seven times during the cropping season. One irrigation was given prior to sowing and the remaining were provided at 25, 40, 55, 70 and 90 days after sowing.

3.3.3.6. Earthing Up and Weeding

Earthing up was done at 50 DAS to make peg penetration easier after flowering. Weeding was done regularly on the bunds and borders. Weed management was done as per the treatment. Pre-emergence application was given at 3 DAS and post-emergence applications at 20 DAS, with the aid of a knapsack sprayer which had a flat fan nozzle fitted in it. A spray-fluid of 500 litres was used for one hectare. Manual hand weedings were given at 20 and 45 DAS. The specifics regarding the herbicides used for the experiment are described in Table 2.

Plate 2. Field preparation and layout

Plate 3. Sowing of crop

Field at 15 DAS

Flowering initiation

Pegging stage

Field at harvest stage

Plate 4. Crop at different growth stages.

Table 2. Specifics regarding the herbicides used in the experiment

Herbicide	**Pendimethalin**	**Imazethapyr**	**Imazethapyr + imazamox**
Chemical name	N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine	5-ethyl-2-(4-isopropyl-4-methyl-5-oxo-4,5-dihydro-1H-imidazol-2-yl) nicotinic acid	Imazethapyr 35 % (w/w) + imazamox 35 % (w/w)
Trade name	Tagpendi®	Pursuit®	Odyssey®
Formulation	30 % EC	10 % SL	70 % WDG
Toxicity label and Acute oral toxicity LD50 (rats)	Yellow >5000 mg kg^{-1}	Green >5000 mg kg^{-1}	Green, >5000 mg kg^{-1}
Manufacturer	TROPICAL AGROSYSTEM PVT. LTD.	BASF	BASF

3.3.3.7. Plant Protection

After pegging stage of crop, incidence of aphids was observed. No specific management practice was adopted as they were below economic threshold level.

3.3.3.8. Harvesting

The crop showed symptoms of yellowing and shedding of leaves on attainment of its full maturity at 110 DAS, which coincided with April 13th, 2020. The harvest was executed by pulling out plants from border rows and net plot area of each treatment, separately. The harvested pods were detached from the plants and spread out and dried in the sun for one week. Dry weight of the haulm and pods were noted.

3.4. OBSERVATIONS

From every plot, five plants were chosen at random and tagged for taking observations at different growth stages *viz.*, 30 DAS, 45 DAS, 60 DAS and at harvest. Main items of observations include growth characters, yield and yield attributes and weed parameters.

3.4.1 Growth Characters

Growth characters of the crop were documented at 30, 45, 60 DAS and at harvest.

3.4.1.1. Plant Height

Plant height was measured starting from the base up to the growing tip of the tagged observational plants and its average values were determined and expressed in centimetres.

3.4.1.2. Number of Branches Per Plant

The count of total number of branches at different growth stages from each tagged observational plant was taken and the mean value was computed.

3.4.1.3. Total Leaf Area Per Plant

Total leaf area was calculated by measuring the length and width of the leaves.

LA = k (L × W)

Where, k is the constant (0.821) (Kathirvelan and Kalaiselvan, 2007)

Total leaf area = Average leaf area x number of leaves.

3.4.2. Yield and Yield Attributes

3.4.2.1. Days to 50 Per Cent Flowering

The average number of days taken by 50 per cent of the plants for their flowers to emerge, in every treatment were separately noted and recorded.

3.4.2.2. Number of Pods Per Plant

From each treatment plot, the count of total number of matured pods from the observational plants were taken and their mean value was recorded as the number of pods per plant.

3.4.2.3. Number of Seeds Per Pod

Fifteen pods from observational plants were randomly selected and their number of seeds were counted and their mean value was recorded as the number seeds per pod.

3.4.2.4. 100 Kernel Weight

The weight of hundred kernels, after drying and shelling, from each plot, were separately recorded in grams as the 100 kernel weight.

3.4.2.5. Kernel Yield

The dry weight of kernels obtained from the plants taken from the net plot area of each treatment, after proper drying and shelling, were recorded. The kernel yield thus obtained from each plot was then converted into kg ha^{-1} and recorded.

3.4.2.6. Haulm Yield

Plants were uprooted from the net plot area and then dried in the sun for three days after harvesting of pods. Average dry weight of the haulm thus attained was expressed in kg ha^{-1}.

3.4.2.7. Harvest Index

Harvest index was computed by using the formula given by Donald and Hamblin, (1976).

$$\text{Harvest index} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}}$$

3.4.2.8. Shelling Percentage

Calculation of shelling percentage was executed using the formula given below

$$\text{Shelling percentage} = \frac{\text{Dry weight of kernels}}{\text{Dry weight of pods}} \times 100$$

3.4.3. Observation on Weeds

Observation on weeds, were taken by using quadrat of 0.5 m^2 in all the treatments and later converted to per m^2. The collected samples were used in the analysis of the following parameters.

3.4.3.1. Weed Flora Composition in the Field

Weed species from the experimental plot were identified and classified into grasses, sedges and broadleaved weeds.

3.4.3.2. Weed Count Per m^2

Weeds were uprooted randomly from an area of $1m^2$ in each plot and were counted species-wise and documented at 15, 30 and 45 DAS.

3.4.3.3. Weed Density Per m²

Weeds taken randomly from an area of $1m^2$ from each plot, were counted and recorded as weed density per m^2 at 15, 30 and 45 DAS.

3.4.3.4. Weed Dry Weight Per m²

Weeds were uprooted from sampling area of each plot, dried in shade and subsequently in hot air oven at 70°C and its dry weight was recorded at 15, 30 and 45 DAS and expressed in g m^{-2}.

3.4.3.5. Weed Control Efficiency (WCE)

WCE was calculated using the formula given by Mani and Gautham (1973)

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

Where,

WCE - Weed control efficiency

WDWC – Weed dry weight in control plot (untreated)

WDWT – Weed dry weight in treated plot

3.4.3.6. Nutrient Removal by Weeds at Flowering (N, P and K uptake)

Weeds were uprooted and collected randomly from 1 m^2 area from each plot at flowering stage and laboratory analysis was carried out for determining N, P and K content. Nutrient uptake by weeds was calculated using the formula,

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Nutrient content (\%)} \times \text{Dry weight of weeds (kg ha}^{-1})}{100}$$

3.4.3.7. Weed Index

The formula used for estimation of weed index was, (Gill and Vijayakumar, 1969)

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

Where,

WI – Weed index

X – Yield obtained from weed free plot (hand weeding treatment)

Y – Yield obtained from treated plot (the plot for which WI has to be determined)

3.4.4. Plant Analysis

Plant analysis for uptake of N, P and K were separately carried out for kernel, husk and haulm. The methods adopted for the analysis of nutrient content in plant parts are presented in Table 3. Total nutrient uptake was computed by adding the nutrient uptake values of haulm, husk and kernel. Nutrient uptake by groundnut at harvest was found out using the formula,

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%) x Dry matter yield (kg ha}^{-1}\text{)}}{100}$$

3.4.5. Soil Analysis

3.4.5.1. Soil pH, EC and Organic carbon

Soil samples from each treatment plots were collected separately after harvest and the soil reaction, electrical conductivity and organic carbon were estimated after the experiment, as per the standard procedures mentioned in Table 1.b.

3.4.5.2. Available Nitrogen, Available Phosphorus, Available Potassium

The estimation of available N, P and K after the experiment were also carried out as per the standard procedures mentioned in Table 1.b.

3.4.6. Incidence of Major Pests and Diseases

Aphids (*Aphis craccivora*) were observed in the field after pegging stages of crop. It was found to be below the economic threshold level. No major diseases were observed in the field.

3.4.7. Economic Analysis

3.4.7.1. Net Income

The cost of cultivation was deducted from gross income to enumerate net income and was expressed in ₹ ha $^{-1}$.

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

3.4.7.2. Benefit Cost Ratio (BCR)

Benefit-cost Ratio was computed as the ratio of gross income to cost of cultivation.

$$\text{BCR} = \frac{\text{Gross income (₹ ha}^{-1}\text{)}}{\text{Cost of cultivation (₹ ha}^{-1}\text{)}}$$

3.4.8. Statistical Analysis

The statistical analysis of data was carried out by using analysis of variance technique for RBD (Gomez and Gomez, 1984) and the testing of significance was done using F test. Critical difference was computed at 5 per cent level of probability, wherever the F values were found significant. The critical difference was used for effective comparison among the treatment means.

Table 3. Methods adopted for the analysis of nutrient content in plant parts.

Particulars	**Method used**	**Reference**
Nitrogen	Modified micro kjeldahl method	Jackson (1973)
Phosphorus	Vanado-molybdo phosphoric yellow colour method using spectrophotometer	Jackson (1973)
Potassium	Flame photometry method	Jackson (1973)

Results

4. RESULTS

The field experiment entitled "Weed management in summer groundnut (*Arachis hypogaea* L.)" was undertaken with the objective of evaluating the effect of weed management on growth and yield of groundnut in the summer rice fallows of *Onattukara* and to work out the economics of cultivation. The experiment was carried out from December 2019 to April 2020 in farmer's field at Vallikunnam panchayath in the *Onattukara* region of Alappuzha district. The data obtained from the experiment were subjected to statistical analysis and the results obtained are presented in this chapter.

4.1. GROWTH CHARACTERS

The data obtained on growth characters of groundnut as affected by different practices of weed management during the study are presented below. The growth parameters were recorded at 30, 45 and 60 DAS and at harvest.

4.1.1. Plant Height

The data is presented in Table 4. The analysis of data revealed that the weed management treatments had significantly influenced the plant height during all the growth stages.

At 30 DAS, taller plants (20.74 cm) were observed with stale seed bed (T_1) and was on par with hand weeding treatment (T_8). Unweeded check (T_9) documented lower plant height (14.41 cm), and was statistically comparable with post-emergence herbicide application treatments (T_2, T_3, T_4) and pre-emergence application (T_6).

At 45 DAS, higher plant height (32.48 cm) was noted for imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) which was comparable with hand weeding treatment (T_8), stale seed bed *fb* 1 hand weeding at 30 DAS (T_1), pre-emergence pendimethalin application treatments (T_6 and T_7). Shorter plants (25.81 cm) were observed in imazethapyr +

Table 4. Effect of weed management on plant height, cm

Treatments	30 DAS	45 DAS	60 DAS	At harvest
T_1 : Stale seed bed *fb* 1 hand weeding at 30 DAS	20.74	30.19	37.89	63.00
T_2 : Imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS	14.72	25.81	31.22	61.00
T_3 : Imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS	14.89	28.70	33.33	60.33
T_4 : Imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS	16.61	28.33	32.67	57.33
T_5 : Imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS	18.00	32.48	37.67	69.00
T_6 : Pendimethalin (PE) @ 1 kg ha^{-1}	16.67	28.85	32.00	59.67
T_7 : Pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS	17.61	30.89	35.33	66.67
T_8 : Hand weeding at 20 DAS and 45 DAS	18.39	32.11	38.11	65.33
T_9 : Unweeded check	14.41	26.67	28.67	55.67
SEm (±)	0.81	1.21	1.94	2.48
CD (0.05)	2.447	3.655	5.863	7.489

imazamox (PoE) @ 40 g ha^{-1} at 20 DAS (T_2), which was on par with post-emergence herbicide application treatments (T_3, T_4), pre-emergence application (T_6) and unweeded check (T_9).

At 60 DAS, hand weeding treatment (T_8) recorded more plant height (38.11 cm) which was comparable with T_1, T_3, T_4, T_5 and T_7. Plant height was lower (28.67 cm) in unweeded check (T_9) which remained statistically at par with post-emergence treatments (T_2, T_3 and T_4) and pendimethalin (PE) @ 1 kg ha^{-1} (T_6).

At harvest, taller plants (69 cm) were observed for imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) which stayed statistically at par with pendimethalin (PE) @ 1 kg ha^{-1} *fb* hand weeding at 30 DAS (T_7), hand weeding at 20 and 45 DAS (T_8) and stale seed bed *fb* 1 hand weeding at 30 DAS (T_1). Lower plant height (55.67 cm) was observed for unweeded check (T_9) and was on par with T_2, T_3, T_4 and T_6.

4.1.2. Number of branches per plant

Data on mean number of branches were given in Table 5. The influence on number of branches by the various treatments employed for management of weeds were significant at every growth stage.

At 30 DAS, post-emergent spraying of imazethapyr @ 70 g ha^{-1} at 20 DAS (T_5) registered more number of branches (6.33) and was on par with stale seed bed (T_1) and hand weeding twice (T_8). Post-emergent spraying of imazethapyr + imazamox @ 40 g ha^{-1} at 20 DAS (T_2) recorded less number of branches (4.00) and was on par with T_6, T_7, T_3, T_4 and unweeded check (T_9).

At 45 DAS also, more number of branches (6.57) were observed in imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) which was comparable with hand weeding (T_8) treatment, stale seed bed *fb* 1 hand weeding at 30 DAS (T_1) and imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS (T_2). Less (5.07) number of branches were recorded in unweeded treatment (T_9) and it was on par with T_2, T_3, T_4, T_6 and T_7.

Table 5. Effect of weed management on number of branches per plant

Treatments	30 DAS	45 DAS	60 DAS	At harvest
T_1 : Stale seed bed *fb* 1 hand weeding at 30 DAS	5.97	6.27	6.50	6.50
T_2 : Imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS	4.00	5.83	6.07	6.20
T_3 : Imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS	4.67	5.63	5.90	6.07
T_4 : Imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS	4.90	5.30	5.67	5.87
T_5 : Imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS	6.33	6.57	6.77	6.97
T_6 : Pendimethalin (PE) @ 1 kg ha^{-1}	4.10	5.70	6.07	6.23
T_7 : Pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS	4.67	5.47	5.90	6.07
T_8 : Hand weeding at 20 DAS and 45 DAS	5.70	6.40	6.10	6.30
T_9 : Unweeded check	4.37	5.07	5.30	5.47
SEm (±)	0.41	0.28	0.22	0.23
CD (0.05)	1.240	0.833	0.662	0.688

At 60 DAS, the total number of branches (6.77) were significantly higher in imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) which was on par with stale seed bed *fb* 1 hand weeding at 30 DAS (T_1). Less number of branches (5.30) were recorded in unweeded check (T_9) which was on par with post-emergence application treatments (T_3, T_4) and pre-emergence application of pendimethalin @ 1 kg ha^{-1} *fb* hand weeding at 30 DAS (T_7).

At harvest, number of branches were higher in T_5, T_1 and T_8. Lower number of branches were observed in T_9, T_3, T_4 and T_7.

4.1.3. Total leaf area per plant

The data on total leaf area per plant is presented in Table 6. The analysed data reveal that leaf area was significantly influenced by the treatments.

At 30 DAS, pendimethalin (PE) @ 1 kg ha^{-1} *fb* hand weeding at 30 DAS (T_7) recorded higher leaf area per plant (376.91 cm^2) and was on par with T_1, T_3, T_5 and T_8.

At 45 DAS, higher leaf area per plant (684.19 cm^2) was registered in pendimethalin *fb* hand weeding at 30 DAS (T_7) which was comparable with imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS (T_3) and hand weeding at 20 and 45 DAS (T_8). Unweeded check (T_9) recorded lower leaf area per plant (500.19 cm^2) and it stayed statistically at par with post-emergence herbicide treatments (T_2 and T_4) and pendimethalin (PE) treatment (T_6).

At 60 DAS and at harvest there were similar trends in the treatment effects on total leaf area. During both stages, it was imazethapyr @ 70 g ha^{-1} at 20 DAS (T_5) which recorded higher leaf area per plant, which was comparable with imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS (T_3) and hand weeding (T_8). At 60 DAS the value recorded was 1114.33 cm^2 and at harvest it was 926.58 cm^2. Lower leaf area (805.13 cm^2) at 60 DAS was documented in unweeded treatment (T_9) and was comparable with all the other treatments except T_3, T_5 and T_8. At harvest, lower leaf area (667.33 cm^2) was recorded again in unweeded check (T_9), which statistically comparable to T_7, T_2, T_6 and T_4.

Table 6. Effect of weed management on total leaf area per plant, cm^2

Treatments	30 DAS	45 DAS	60 DAS	At harvest
T_1 : Stale seed bed *fb* 1 hand weeding at 30 DAS	353.47	583.81	946.30	803.94
T_2 : Imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS	302.95	536.96	938.89	757.67
T_3 : Imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS	357.91	605.94	1053.44	855.78
T_4 : Imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS	294.80	507.19	851.56	706.67
T_5 : Imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS	358.41	589.56	1114.33	926.58
T_6 : Pendimethalin (PE) @ 1 kg ha^{-1}	322.94	559.27	880.59	704.50
T_7 : Pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS	376.91	684.19	946.31	765.90
T_8 : Hand weeding at 20 DAS and 45 DAS	375.16	670.91	982.21	806.67
T_9 : Unweeded check	290.68	500.19	805.13	667.33
SEm (±)	17.56	27.24	49.11	42.50
CD (0.05)	53.084	82.375	148.494	128.511

4.2. YIELD AND YIELD ATTRIBUTES

4.2.1. Days to 50 per cent flowering

The different weed management treatments significantly influenced the days to 50 per cent flowering and the data obtained are presented in Table 7.

Imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS (T_4) took lesser days (38) to complete 50 per cent flowering in comparison with rest of the treatments and remained statistically at par with pendimethalin (PE) *fb* hand weeding (T_7) and unweeded check (T_9). Imazethapyr @ 70 g ha^{-1} at 20 DAS (T_5) took more days (41.67) to complete 50 per cent flowering, which was on par with post-emergence application of imazethapyr + imazamox at 20 DAS (T_2, T_3), stale seed bed *fb* 1 hand weeding at 30 DAS (T_1), pre-emergence application of pendimethalin @ 1 kg ha^{-1} (T_6) and hand weeding at 20 and 45 DAS (T_8).

4.2.2. Number of pods per plant

The data on mean number of pods per plant are presented in Table 7. The treatment effects were significant with respect to the number of pods.

The number of pods were higher (43.20) in imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) and it was comparable with imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS (T_3) and pendimethalin (PE) *fb* hand weeding at 30 DAS (T_7). Lower number of pods (19.33) were registered in unweeded check (T_9), which was on par with pendimethalin @ 1 kg ha^{-1} applied as pre-emergence (T_6).

4.2.3. Number of seeds per pod

The mean data obtained are presented in Table 8. The number of seeds per pod was not significantly influenced by the weed management treatments. The mean value varied from 1.7 to 2.0.

Table 7. Effect of weed management on days to 50 per cent flowering and number of pods per plant

Treatments	Days to 50 per cent flowering	Number of pods per plant
T_1 : Stale seed bed *fb* 1 hand weeding at 30 DAS	40.00	34.73
T_2 : Imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS	40.67	34.07
T_3 : Imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS	40.33	39.47
T_4 : Imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS	38.00	32.40
T_5 : Imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS	41.67	43.20
T_6 : Pendimethalin (PE) @ 1 kg ha^{-1}	40.00	24.40
T_7 : Pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS	38.33	37.60
T_8 : Hand weeding at 20 DAS and 45 DAS	40.33	32.67
T_9 : Unweeded check	38.33	19.33
SEm (±)	0.66	2.80
CD (0.05)	2.002	8.464

Table 8. Effect of weed management on number of seeds per pod and 100 kernel weight

Treatments	Number of seeds per pod	100 kernel weight (g)
T_1 : Stale seed bed *fb* 1 hand weeding at 30 DAS	1.9	41.7
T_2 : Imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS	1.8	37.7
T_3 : Imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS	1.9	41.3
T_4 : Imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS	1.8	46.0
T_5 : Imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS	2.0	48.3
T_6 : Pendimethalin (PE) @ 1 kg ha^{-1}	1.9	37.0
T_7 : Pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS	1.9	42.0
T_8 : Hand weeding at 20 DAS and 45 DAS	1.8	39.7
T_9 : Unweeded check	1.7	32.3
SEm (±)	0.08	2.41
CD (0.05)	NS	7.300

4.2.4. 100 Kernel weight

The data pertaining to 100 kernel weight are presented in Table 8. The weed management treatments significantly influenced 100 kernel weight.

Higher 100 kernel weight (48.3 g) was recorded in imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) which was comparable with post-emergence application treatments (T_3, T_4), stale seed bed *fb* 1 hand weeding at 30 DAS (T_1) and pendimethalin (PE) *fb* hand weeding at 30 DAS (T_7). Lower 100 kernel weight (32.3 g) was registered in unweeded plot (T_9) which remained statistically at par with pendimethalin (PE) @ 1 kg ha^{-1} (T_6) and imazethapyr + imazamox applied as post-emergence herbicide @ 40 g ha^{-1} at 20 DAS (T_2).

4.2.5 Kernel yield

The perusal of data reveals that the treatment effects had a significant influence on kernel yield and the data are presented in Table 9.

Higher kernel yield (1652 kg ha^{-1}) was obtained from imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5), which was on par with hand weeding treatment (T_8), imazethapyr + imazamox (PoE) @ 70 g ha^{-1} at 20 DAS (T_3) and stale seed bed treatment (T_1). Lowest yield (857 kg ha^{-1}) was attained in unweeded check (T_9), which was inferior to every other treatment.

4.2.6. Haulm yield

The results pertaining to haulm yield are presented in Table 9.

Higher haulm yield (3502 kg ha^{-1}) was recorded with imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) and was on par with all the treatments except T_9 and T_2. Unweeded check (T_9) documented lower haulm yield (2300 kg ha^{-1}) and was on par with imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS (T_2).

Table 9. Effect of weed management on kernel yield and haulm yield, kg ha^{-1}

Treatments	Kernel yield	Haulm yield
T_1 : Stale seed bed *fb* 1 hand weeding at 30 DAS	1522	3433
T_2 : Imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS	1154	2813
T_3 : Imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS	1402	3300
T_4 : Imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS	1343	3053
T_5 : Imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS	1652	3502
T_6 : Pendimethalin (PE) @ 1 kg ha^{-1}	1270	3130
T_7 : Pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS	1333	3052
T_8 : Hand weeding at 20 DAS and 45 DAS	1588	3467
T_9 : Unweeded check	857	2300
SEm (±)	96.61	215.72
CD (0.05)	292.124	652.290

4.2.7. Harvest index

The weed management treatments had significant impacts on harvest index and the mean values are presented in Table 10.

Greater percentage of harvest index (0.393) was documented in post-emergence application of imazethapyr @ 70 g ha^{-1} at 20 DAS (T_5). It stayed statistically at par with every other treatment except imazethapyr + imazamox (T_2) and unweeded check (T_9).

4.2.8. Shelling percentage

The mean shelling percentage is presented in Table 10. All the treatments had an influence on shelling percentage.

Imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) registered higher shelling percentage (72.95) and was statistically comparable with stale seed bed (T_1), post-emergence applications (T_2 and T_4), pendimethalin (PE) *fb* hand weeding (T_7) and hand weeding treatment (T_8). Unweeded check (T_9), recorded lower shelling percentage (66.87). It was comparable with post-emergence treatments (T_2, T_4, T_3) and pre-emergence application of pendimethalin (T_6).

4.3. OBSERVATION ON WEEDS

4.3.1. Weed flora composition in the field

The data regarding the weed flora composition is given in Table 11. The predominant weed flora observed was broadleaved weeds and *Portulaca oleraceae* was the most dominant weed species. Other broadleaved weeds were *Cleome rutidosperma, Melochia corchorifolia, Synedrella nodiflora, Phyllanthus niruri, Heliotropium indicum.* There were only two grassy weeds, *Cynodon dactylon* and *Eleusine indica*. *Cyperus rotundus* was the only sedge noted in the investigational plots.

4.3.2. Weed Count per m^2

Table 10. Effect of weed management on harvest index and shelling percentage

Treatments	Harvest index	Shelling percentage
T_1 : Stale seed bed *fb* 1 hand weeding at 30 DAS	0.381	71.82
T_2 : Imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS	0.373	69.28
T_3 : Imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS	0.382	68.22
T_4 : Imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS	0.388	69.27
T_5 : Imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS	0.393	72.95
T_6 : Pendimethalin (PE) @ 1 kg ha^{-1}	0.376	67.40
T_7 : Pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS	0.382	70.79
T_8 : Hand weeding at 20 DAS and 45 DAS	0.392	71.15
T_9 : Unweeded check	0.358	66.87
SEm (±)	0.01	1.24
CD (0.05)	0.020	3.749

Table 11. Weed flora composition in the field

Scientific name	Common name	Malayalam name
Broadleaved weeds		
Portulaca oleraceae	Common purslane	Kozhuppa
Cleome rutidosperma	Fringed spider flower	Neelavela
Melochia corchorifolia	Chocolate weed	Cheruvuram
Synedrella nodiflora	Cindrella weed	Mudiyethra pacha
Phyllanthus niruri	Stone breaker weed	Keezharnelli
Heliotropium indicum	Indian heliotrope	Therkkada
Grasses		
Cynodon dactylon	Bermuda grass	Karuka pullu
Eluesine indica	Indian goose grass	Kaattu thina
Sedges		
Cyperus rotundus	Purple nut sedge	Muthanga

The results pertaining to weed count per m^2 are presented in Tables 12, 13 and 14. Weed count of grassy weeds, sedges and broadleaved weeds were taken at 15 DAS, 30 DAS and 45 DAS.

4.3.2.1. Grasses

The treatments had a significant influence on the population of grasses at 15 and 30 DAS.

At 15 DAS, grassy weed was lower (1.33) per m^2 in T_6 and T_7 (pre-emergence herbicide treatments) and were comparable with manual weeding treatment (T_8).

At 30 DAS, less grassy weeds (1.33) per m^2 was registered under pendimethalin (PE) @ 1 kg ha^{-1} (T_6) and imazethapyr (PoE) @ 70 g ha^{-1} (T_5), and hand weeding (T_8) which were comparable with post-emergence treatments (T_3 and T_4), pendimethalin *fb* hand weeding (T_7). Higher grassy weed count (12) was recorded in stale seed bed (T_1). At 45 DAS, the weed management treatments did not have any significant effect on the grassy weeds.

4.3.2.2. Sedges

The weed management treatments did not exert any significant influence on the number of sedges at any of the growth stages of groundnut.

4.3.2.3. Broadleaved Weeds

The assessment of weed count data of broadleaved weeds revealed that they were influenced by management of weeds at 15, 30 and 45 DAS.

At 15 DAS, lower population of broadleaved weeds were observed in pre-emergence herbicide treatments (T_6 and T_7).

Pendimethalin (PE) *fb* hand weeding at 30 DAS (T_7) catalogued lower broadleaved weeds (121.66) at 30 DAS, and was on par with post-emergence application treatments (T_2, T_4, T_5) and hand weeding treatment (T_8).

At 45 DAS, stale seed bed *fb* 1 hand weeding at 30 DAS (T_1) recorded lower population of broadleaved weeds (96.00) and was on par with T_5 and T_7.

Broadleaved weeds were more in unweeded check (T_9) in all the stages.

Table 12. Effect of weed management on weed count per m^2 at 15 DAS.

Treatments	Weed count per m^2		
	Grasses	Sedges	Broadleaved weeds
T_1 : Stale seed bed *fb* 1 hand weeding at 30 DAS	2.97 (8.33)	1.96 (3.33)	6.13 (37.00)
T_2 : Imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS	3.44 (11.00)	2.03 (3.66)	13.04 (171.66)
T_3 : Imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS	3.10 (9.00)	1.85 (3.00)	12.25 (150.00)
T_4 : Imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS	3.94 (15.00)	3.09 (9.33)	14.64 (217.00)
T_5 : Imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS	4.10 (16.00)	2.08 (4.00)	14.40 (206.66)
T_6 : Pendimethalin (PE) @ 1 kg ha^{-1}	1.41 (1.33)	1.00 (0.00)	4.70 (21.33)
T_7 : Pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS	1.41 (1.33)	1.00 (0.0)	4.59 (20.33)
T_8 : Hand weeding at 20 DAS and 45 DAS	2.71 (8.00)	1.82 (2.66)	9.60 (91.66)
T_9 : Unweeded check	3.73 (13.33)	1.67 (2.66)	15.81 (250.66)
SEm (±)	0.52	0.54	0.64
CD (0.05)	1.561	NS	1.944

*Original values in the parenthesis are subjected to $\sqrt{x+1}$ transformation.

Table 13. Effect of weed management on weed count per m^2 at 30 DAS.

Treatments	Weed count per m^2		
	Grasses	Sedges	Broadleaved weeds
T_1 : Stale seed bed *fb* 1 hand weeding at 30 DAS	3.53 (12.00)	1.41 (1.33)	13.19 (174.00)
T_2 : Imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS	2.73 (6.66)	1.00 (0.00)	11.52 (132.00)
T_3 : Imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS	2.08 (4.00)	1.41 (1.33)	13.09 (170.33)
T_4 : Imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS	2.68 (6.66)	1.00 (0.00)	12.36 (152.00)
T_5 : Imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS	1.41 (1.33)	1.67 (2.66)	11.79 (138.00)
T_6 : Pendimethalin (PE) @ 1 kg ha^{-1}	1.41 (1.33)	1.00 (0.00)	12.93 (166.33)
T_7 : Pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS	2.54 (6.66)	1.00 (0.00)	11.04 (121.66)
T_8 : Hand weeding at 20 DAS and 45 DAS	1.49 (1.33)	1.00 (0.00)	11.18 (126.33)
T_9 : Unweeded check	3.12 (9.33)	1.82 (2.66)	14.52 (210.00)
SEm (±)	0.44	0.54	0.49
CD (0.05)	1.314	NS	1.486

*Original values in the parenthesis are subjected to $\sqrt{x+1}$ transformation.

Table 14. Effect of weed management on weed count per m^2 at 45 DAS

Treatments	Weed count per m^2		
	Grasses	Sedges	Broadleaved weeds
T_1 : Stale seed bed *fb* 1 hand weeding at 30 DAS	1.47 (1.33)	1.41 (1.33)	9.83 (96.00)
T_2 : Imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS	1.61 (1.66)	1.82 (2.66)	16.73 (279.66)
T_3 : Imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS	1.61 (1.66)	1.00 (0.00)	16.64 (277.00)
T_4 : Imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS	2.21 (4.00)	1.00 (0.00)	12.47 (154.66)
T_5 : Imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS	1.38 (1.00)	1.41 (1.33)	12.09 (145.33)
T_6 : Pendimethalin (PE) @ 1 kg ha^{-1}	1.66 (2.00)	1.00 (0.00)	15.71 (253.66)
T_7 : Pendimethalin (PE) @ 1 kg ha^{-1} fb 1 hand weeding at 30 DAS	1.96 (3.33)	1.00 (0.00)	10.28 (105.00)
T_8 : Hand weeding at 20 DAS and 45 DAS	1.55 (1.66)	1.00 (0.00)	13.12 (172.00)
T_9 : Unweeded check	2.37 (4.66)	1.67 (2.66)	18.47 (340.33)
SEm (±)	0.30	0.34	0.83
CD (0.05)	NS	NS	2.507

*Original values in the parenthesis are subjected to √x+1 transformation.

4.3.3. Weed density per m^2

Weed density per m^2 was recorded at 15, 30 and 45 DAS. The summary of data reveals that the treatments significantly influenced the weed density and the data are shown in Table 15.

At 15 DAS, pendimethalin + hand weeding (T_7) recorded lower weed density per m^2 (22.22) which stayed statistically at par with pendimethalin (PE) @ 1 kg ha^{-1} (T_6). Weed density per m^2 (267.17) was higher in unweeded check (T_9).

At 30 DAS, T_8 (hand weeding at 20 and 45 DAS) documented lower weed density (127.89) and was comparable with post-emergence herbicide application treatments (T_2, T_5) and pendimethalin (PE) *fb* hand weeding (T_7). Higher weed density per m^2 (221.84) was observed in unweeded check (T_9) which was inferior to every other treatment.

At 45 DAS, stale seed bed + hand weeding at 30 DAS (T_1) recorded lower weeds density per m^2 (100.00) which remained statistically at par with post-emergence herbicide application treatment (T_5) and pendimethalin (PE) *fb* hand weeding at 30 DAS (T_7). More weeds per m^2 (345.83) was observed in unweeded check (T_9) and was comparable with T_2 and $T_{3.}$

4.3.4. Weed dry weight per m^2

The mean dry weight of weeds at 15, 30 and 45 DAS are given in Table 16.

At 15 DAS, pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding (T_7) recorded lower dry weight of weeds (14.67 g) in comparison to rest of the treatments and was comparable with stale seed bed *fb* 1 hand weeding at 30 DAS (T_1) and pendimethalin (PE) (T_6). Higher dry weight (176.33 g) was documented in unweeded treatment (T_9).

At 30 DAS, less weed dry weight (83.75 g) was registered in T_8 (hand weeding). It was comparable to post-emergence herbicide application treatments (T_3 and T_5) and pendimethalin (PE) *fb* hand weeding (T_7). Higher dry weight (141.66 g) was observed in unweeded check (T_9).

Stale seed bed *fb* hand weeding (T_1) documented less dry weight at 45 DAS (80 g), and was statistically comparable with post-emergent herbicide application treatments

Table 15. Effect of weed management on weed density per m^2

Treatments	Weed density per m^2		
	15 DAS	30 DAS	45 DAS
T_1 : Stale seed bed *fb* 1 hand weeding at 30 DAS	6.97 (48.49)	13.70 (186.60)	10.03 (100.00)
T_2 : Imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS	13.64 (186.87)	11.83 (139.20)	16.85 (283.75)
T_3 : Imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS	12.89 (165.66)	13.30 (176.06)	16.68 (278.33)
T_4 : Imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS	15.48 (241.92)	12.64 (159.04)	12.61 (158.33)
T_5 : Imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS	15.07 (226.77)	11.94 (141.67)	12.16 (147.08)
T_6 : Pendimethalin (PE) @ 1 kg ha^{-1}	4.90 (23.23)	13.01 (168.26)	15.76 (255.00)
T_7 : Pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS	4.80 (22.22)	11.36 (128.00)	10.49 (109.17)
T_8 : Hand weeding at 20 DAS and 45 DAS	10.16 (103.03)	11.35 (127.89)	13.17 (173.33)
T_9 : Unweeded check	16.31 (267.17)	14.93 (221.84)	18.62 (345.83)
SEm (±)	0.66	0.26	0.83
CD (0.05)	1.991	0.789	2.502

*Original values in the parenthesis are subjected to $\sqrt{x+1}$ transformation.

Table 16. Effect of weed management on weed dry weight per m^2, g

Treatments	Weed dry weight		
	15 DAS	30 DAS	45 DAS
T_1 : Stale seed bed *fb* 1 hand weeding at 30 DAS	32.00	133.93	80.00
T_2 : Imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS	123.33	116.20	227.00
T_3 : Imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS	109.33	91.87	130.67
T_4 : Imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS	159.67	104.97	222.67
T_5 : Imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS	149.67	87.37	87.33
T_6 : Pendimethalin (PE) @ 1 kg ha^{-1}	15.33	111.05	204.00
T_7 : Pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS	14.67	88.44	117.67
T_8 : Hand weeding at 20 DAS and 45 DAS	68.00	83.75	138.67
T_9 : Unweeded check	176.33	141.66	276.67
SEm (±)	11.81	6.54	19.77
CD (0.05)	35.705	19.787	59.767

(T_3 and T_5), pendimethalin (PE) *fb* hand weeding at 30 DAS (T_7) and hand weeding treatment (T_8). The weed dry weight was higher (276.67 g) in unweeded check (T_9).

4.3.5. Weed control efficiency

The mean data on WCE at 15, 30 and 45 DAS are presented in Table 17.

At 15 DAS, the highest weed control efficiency (91.41 %) was obtained under pendimethalin (PE) + hand weeding at 30 DAS (T_7) and was statistically comparable with T_1 and T_6. At 30 DAS, hand weeding treatment (T_8) recorded the highest WCE (40.96 %) and was followed by T_5 (37.91 %), T_3, T_4 and T_7. At 45 DAS, highest weed control efficiency (70.95 %) was registered under stale seed bed treatment (T_1), closely followed by T_5 (68.44 %), T_3, T_7 and T_8. The lowest weed control efficiency at all the stages, were recorded in unweeded check (T_9).

4.3.6. Nutrient removal by weeds at flowering stage

The nutrient removal by weeds (N, P and K uptake) at flowering stage was influenced significantly by weed management. The mean data are shown in Table 18.

The results revealed that weed nitrogen uptake (1.84 kg ha^{-1}) was lower in stale seed bed *fb* 1 hand weeding at 30 DAS (T_1), followed by imazethapyr (PoE) (T_4 and T_5), pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding (T_7) and hand weeding at 20 and 45 DAS (T_8). Higher N uptake by weeds (6.29 kg ha^{-1}) were observed in unweeded check (T_9).

Lower P uptake (0.18 kg ha^{-1}) was documented in stale seed bed *fb* 1 hand weeding at 30 DAS (T_1) and was statistically comparable with post-emergence application of imazethapyr (T_4 and T_5), pendimethalin (PE) *fb* hand weeding (T_7) and hand weeding at 20 and 45 DAS (T_8). Higher P uptake (0.63 kg ha^{-1}) was recorded in T_3, T_2 and T_9.

K uptake (1.47 kg ha^{-1}) was lower in pendimethalin (PE) *fb* 1 hand weeding at 30 DAS (T_7) and was comparable with imazethapyr (PoE) (T_4 and T_5), hand weeding at 20

Table 17. Weed control efficiency at different growth stages, as influenced by weed management treatments, %

Treatments	Weed control efficiency		
	15 DAS	30 DAS	45 DAS
T_1 : Stale seed bed *fb* 1 hand weeding at 30 DAS	9.09 (81.68)	2.50 (5.57)	8.48 (70.95)
T_2 : Imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS	5.56 (30.12)	4.21 (17.67)	4.33 (18.18)
T_3 : Imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS	6.17 (37.22)	5.96 (34.84)	7.34 (52.90)
T_4 : Imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS	3.11 (10.02)	5.01 (25.38)	4.24 (19.23)
T_5 : Imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS	3.79 (14.09)	6.21 (37.91)	8.32 (68.44)
T_6 : Pendimethalin (PE) @ 1 kg ha^{-1}	9.58 (90.76)	4.63 (21.13)	4.43 (25.18)
T_7 : Pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS	9.61 (91.41)	6.21 (37.57)	7.63 (57.35)
T_8 : Hand weeding at 20 DAS and 45 DAS	7.76 (59.78)	6.44 (40.96)	7.09 (49.54)
T_9 : Unweeded check	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
SEm (±)	0.41	0.48	0.72
CD (0.05)	1.250	1.439	2.172

*Original values in the parenthesis are subjected to √x+1 transformation.

Table 18. Nutrient removal by weeds as influenced by weed management at flowering stage, kg ha^{-1}

Treatments	Nutrient uptake		
	N	P	K
T_1 : Stale seed bed *fb* 1 hand weeding at 30 DAS	1.84	0.18	2.10
T_2 : Imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS	5.00	0.59	4.01
T_3 : Imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS	5.42	0.63	3.42
T_4 : Imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS	3.17	0.31	2.73
T_5 : Imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS	2.40	0.27	2.02
T_6 : Pendimethalin (PE) @ 1 kg ha^{-1}	4.70	0.47	3.61
T_7 : Pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS	1.87	0.22	1.47
T_8 : Hand weeding at 20 DAS and 45 DAS	3.17	0.31	3.01
T_9 : Unweeded check	6.29	0.59	5.76
SEm (±)	0.55	0.05	0.53
CD (0.05)	1.672	0.159	1.614

and 45 DAS (T_8) and stale seed bed *fb* hand weeding (T_1). Unweeded check (T_9) recorded higher uptake of K (5.76 kg ha^{-1}), which was inferior to every other treatments.

4.3.7. Weed index

The mean data of weed index is presented in Table 19. The weed index ranged from -9.94 to 46.83 per cent over the treatments.

Negative value of weed index (-9.94 %) in imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) indicated that it was superior over the hand weeding treatment (T_8). It was on par with T_1 and T_3. The highest weed index (46.83 %) was recorded for unweeded check (T_9).

4.4. PLANT ANALYSIS

4.4.1. N, P and K uptake by crop at harvest

N, P and K uptake by crop at harvest are presented in Table 20.

The results revealed that N uptake was higher (173 kg ha^{-1}) in post-emergence application of imazethapyr @ 70 g ha^{-1} at 20 DAS (T_5), which was on par with pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS (T_7) and hand weeding at 20 and 45 DAS (T_8). Less N (114.15 kg ha^{-1}) uptake was observed in unweeded check (T_9).

Higher P uptake (16.36 kg ha^{-1}) was recorded in post-emergence application of imazethapyr @ 70 g ha^{-1} at 20 DAS (T_5), which was on par with pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS (T_7) and hand weeding at 20 and 45 DAS (T_8). Less P uptake (7.78 kg ha^{-1}) was recorded in unweeded check (T_9).

Higher K uptake (83.53 kg ha^{-1}) was recorded in post-emergence application of imazethapyr @ 70 g ha^{-1} at 20 DAS (T_5), which was comparable with pre-emergence treatments (T_6 and T_7) and imazethapyr (PoE) @ 37.5 g ha^{-1} (T_4). Lower K uptake was recorded in T_1, T_2, T_3, T_4, T_8 and T_9.

Table 19. Weed index as influenced by weed management treatments, %

Treatments	Weed index
T_1 : Stale seed bed *fb* 1 hand weeding at 30 DAS	4.02
T_2 : Imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS	25.99
T_3 : Imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS	5.62
T_4 : Imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS	16.31
T_5 : Imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS	-9.94
T_6 : Pendimethalin (PE) @ 1 kg ha^{-1}	21.18
T_7 : Pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS	15.69
T_8 : Hand weeding at 20 DAS and 45 DAS	0.00
T_9 : Unweeded check	46.83
SEm (±)	7.95
CD (0.05)	24.032

Table 20. Effect of weed management on N, P and K uptake by crop at harvest, kg ha^{-1}

Treatments	N uptake	P uptake	K uptake
ST$_1$: Stale seed bed *fb* 1 hand weeding at 30 DAS	147.38	10.20	58.53
T$_2$: Imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS	138.53	10.31	58.33
T$_3$: Imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS	132.85	10.14	62.55
T$_4$: Imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS	119.64	9.29	69.15
T$_5$: Imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS	173.00	16.36	83.53
T$_6$: Pendimethalin (PE) @ 1 kg ha^{-1}	142.51	11.51	76.15
T$_7$: Pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS	152.92	16.32	72.54
T$_8$: Hand weeding at 20 DAS and 45 DAS	151.44	14.08	54.87
T$_9$: Unweeded check	114.15	7.78	59.69
SEm (±)	7.92	1.52	5.73
CD (0.05)	23.954	4.586	17.316

4.5. SOIL ANALYSIS AFTER THE EXPERIMENT

Soil samples after the experiment were analysed for pH, EC, organic carbon, available N, P and K status. The mean data are presented in Table 21 and 22.

4.5.1. Soil pH, EC and organic carbon

The results of soil pH, EC and organic carbon after the experiment revealed that these were not influenced by the treatments. The soil pH ranged from 5.67 (T_6) to 5.82 (T_5). The electrical conductivity varied from 0.04 dS m^{-1} (T_1) to 0.08 dS m^{-1} (T_7). The organic carbon status of the soil also varied between 0.75 per cent (T_3) and 1.20 per cent (T_7).

4.5.2. Available N, P and K

Weed management resulted in a buildup of N in the soil generally, in comparison with initial nitrogen status of soil. Higher available N (255.06 kg ha^{-1}) was registered under the treatment hand weeding at 20 and 45 DAS (T_8), which was on par with post-emergence application of imazethapyr (T_4), stale seed bed (T_1), pre-emergence treatments (T_6 and T_7) and unweeded check (T_9). The available N content (194.43 kg ha^{-1}) was low in post-emergence application of imazethapyr + imazamox @ 40 g ha^{-1} at 20 DAS (T_2).

Weed management did not influence available P and K, significantly. The available P varied from 35.75 kg ha^{-1} (T_8) to 59.03 kg ha^{-1} (T_5). Available K ranged from 186.67 kg ha^{-1} (T_8) to 246.40 kg ha^{-1} (T_4).

4.6. INCIDENCE OF PEST AND DISEASES

Aphids (*Aphis craccivora*) were observed towards later stages of the crop. No specific management practices were adopted as it was below economic threshold level. No diseases were observed in the field during the crop period.

4.7. ECONOMIC ANALYSIS

Table 21. Effect of weed management on soil pH, EC and organic carbon status of soil after the experiment.

Treatments	pH	EC ($dS\ m^{-1}$)	OC (%)
T_1 : Stale seed bed *fb* 1 hand weeding at 30 DAS	5.76	0.04	1.11
T_2 : Imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS	5.80	0.06	1.03
T_3 : Imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS	5.78	0.05	0.75
T_4 : Imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS	5.71	0.06	1.03
T_5 : Imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS	5.82	0.06	0.99
T_6 : Pendimethalin (PE) @ 1 kg ha^{-1}	5.67	0.06	1.08
T_7 : Pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS	5.72	0.08	1.20
T_8 : Hand weeding at 20 DAS and 45 DAS	5.77	0.07	0.90
T_9 : Unweeded check	5.80	0.05	0.94
SEm (±)	0.10	0.01	0.14
CD (0.05)	NS	NS	NS

Table 22. Effect of weed management on available N, P and K status of soil after the experiment, kg ha^{-1}

Treatments	Available N	Available P	Available K
T_1 : Stale seed bed *fb* 1 hand weeding at 30 DAS	225.79	50.97	231.47
T_2 : Imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS	194.43	48.28	216.53
T_3 : Imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS	217.43	41.49	238.93
T_4 : Imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS	238.34	36.61	246.40
T_5 : Imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS	204.89	59.03	205.33
T_6 : Pendimethalin (PE) @ 1 kg ha^{-1}	238.34	50.48	194.13
T_7 : Pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS	246.70	45.10	224.00
T_8 : Hand weeding at 20 DAS and 45 DAS	255.06	35.75	186.67
T_9 : Unweeded check	234.16	56.65	197.87
SEm (±)	11.61	5.91	17.52
CD (0.05)	35.119	NS	NS

Table 23. Effect of weed management on Net income and benefit cost ratio.

Treatments	Net income (₹ ha^{-1})	BCR
T_1 : Stale seed bed *fb* 1 hand weeding at 30 DAS	72471	2.05
T_2 : Imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS	42919	1.66
T_3 : Imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS	72794	2.12
T_4 : Imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS	57918	1.89
T_5 : Imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS	95611	2.46
T_6 : Pendimethalin (PE) @ 1 kg ha^{-1}	50308	1.78
T_7 : Pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS	52585	1.74
T_8 : Hand weeding at 20 DAS and 45 DAS	73079	1.99
T_9 : Unweeded check	16099	1.26

The net income and benefit-cost ratio were calculated and presented in Table 23.

The highest net income (₹ 95611) was recorded for imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) followed by hand weeding at 20 and 45 DAS (T_8) and imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS (T_3). The B-C ratio (2.46) was also higher in imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) followed by T_3 (imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS) and T_1 (stale seed bed *fb* 1 hand weeding at 30 DAS) with a BCR of 2.12 and 2.05, respectively.

Discussion

5. DISCUSSION

An experiment entitled "Weed management in summer groundnut (*Arachis hypogaea* L.)" was undertaken with the objectives to find out the best weed management option for summer groundnut in the *Onattukara* tract and to work out the economics of cultivation. The results of the experiment that were already presented in the previous chapter are discussed below.

5.1. WEED FLORA IN EXPERIMENTAL FIELD

The weed flora of a crop varied with agro ecological units and crop management practices. Weeds in experimental field comprised of diverse species of grasses, broadleaved weeds and sedge. The sandy loam soil of *Onattukara* tract favours predominance of broadleaved weeds in field. The percentage composition of weeds in the experimental site is graphically illustrated in Fig. 3. The most dominant weed species observed was *Portulaca oleraceae*. There were only two grassy weeds, *Cynodon dactylon* and *Eleusine indica. Cyperus rotundus* was the only sedge that was present in the experimental field. Similar results were reported by Nambi *et al.* (2019).

5.1.1. Influence of Weed Management on Weed Population

Groundnut crop has sluggish rate of growth up-to 6 WAS so that the plants are gravely affected by presence of weeds at the early stage. Lower population of weeds creates sufficient space for growth of roots and consequently nodulation in groundnut (Dayal, 2004). The population of grasses was influenced significantly by the treatments at 15 and 30 DAS. Grassy weeds were controlled by pendimethalin (PE) during the initial stages of crop. The post-emergence application treatments (T_3, T_4 and T_5) managed grassy weeds at 30 DAS. The influence of treatments on grasses was not significant at 45

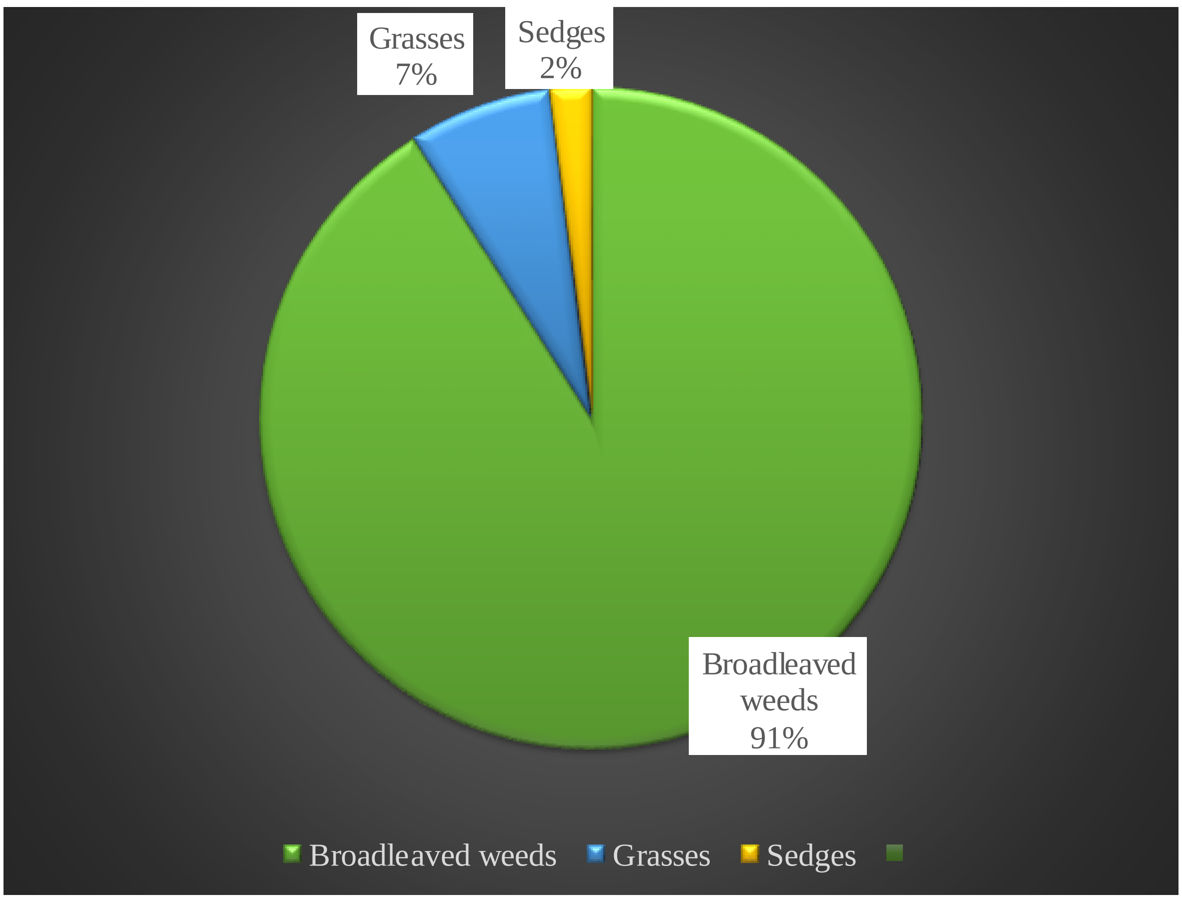

Fig. 3. Percentage composition of weeds

DAS. Tamang *et al.* (2015) reported that weedicides *viz.,* pendimethalin 30 EC + imazethapyr 2 EC, pendimethalin, imazethapyr, and fenoxaprop-p-ethyl were identified to be effectual in managing the population of grasses. Weed population (Fig. 4a, 4b, 4c) at all growth stages revealed that there was no significant variation in population of sedges. This may be due to their lower population density.

At 15 DAS, broadleaved weeds were lower in pre-emergence herbicide treatments. At 30 DAS, broadleaved weeds were lower in herbicide treatments (T_2, T_4, T_5 and T_7). Kalhapure *et al.* (2013) reported that imazethapyr was the cause for inhibition of acetolactate synthase (ALS) or acetohydroxyacid synthase (AHAS) in broadleaved weeds which led to demise of these weeds at early stage. Stale seed bed following hand weeding at 30 DAS (T_1) gave good control of broadleaved weeds at 45 DAS which remained statistically at par with imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) and pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS (T_7). This might be due to the efficiency of imazethapyr at higher dose (70 g ha^{-1}) in managing all categories of weeds. Hand weeding at 30 DAS in T_1 and T_7 also gave good control of weeds at 45 DAS. Dubey and Gangwar (2012) ascertained that reduced weed dry weight, weed index and increased WCE were detected when imazethapyr was applied as post-emergence and when two hand weedings were given in groundnut.

Weed density is related to the total population of grasses, broadleaved weeds and sedges (Fig. 5). At 15 DAS, pre-emergence herbicide treatments showed the lowest weed density. At 30 DAS, lower weed density was documented in T_2, T_5, T_7 and T_8. At 45 DAS, weed density was lower in stale seed bed *fb* 1 hand weeding at 30 DAS (T_1), imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) and pendimethalin (PE) *fb* hand weeding at 30 DAS (T_7). Olorunmaiye and Olorunmaiye (2009), mentioned that pre-emergentce weedicide treatments without the aid of additional weeding with hoe cannot create a season long control of weeds as a result of their short period of persistence.

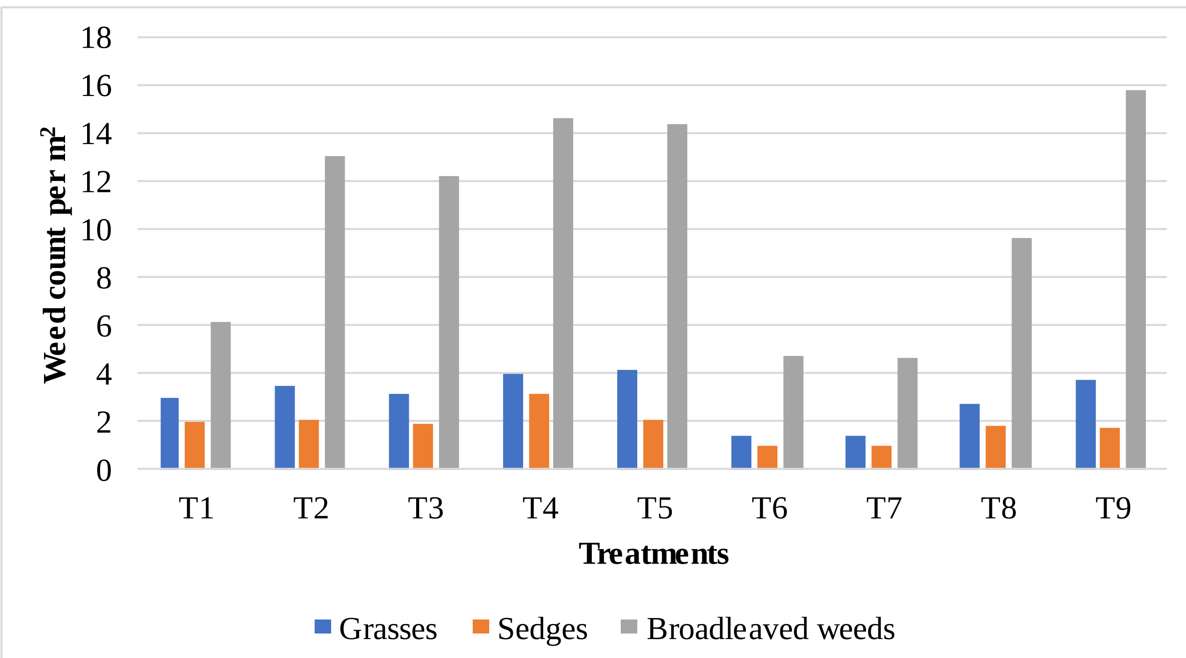

Fig. 4a. Effect of weed management on weed count per m^2 at 15 DAS

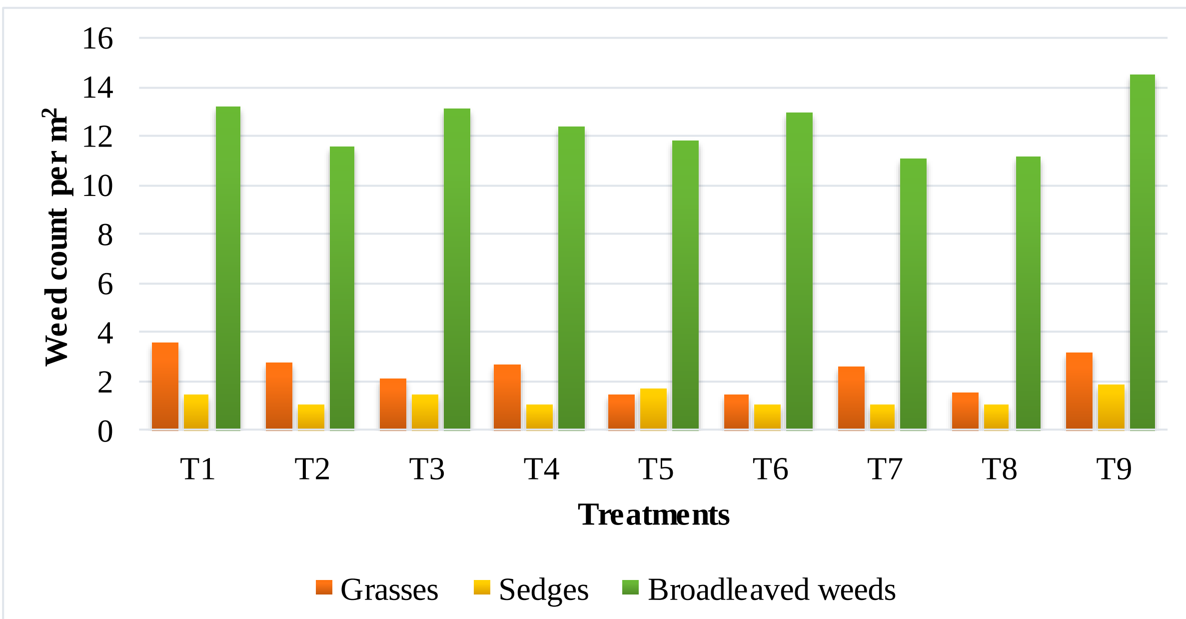

Fig. 4b. Effect of weed management on weed count per m^2 at 30 DAS

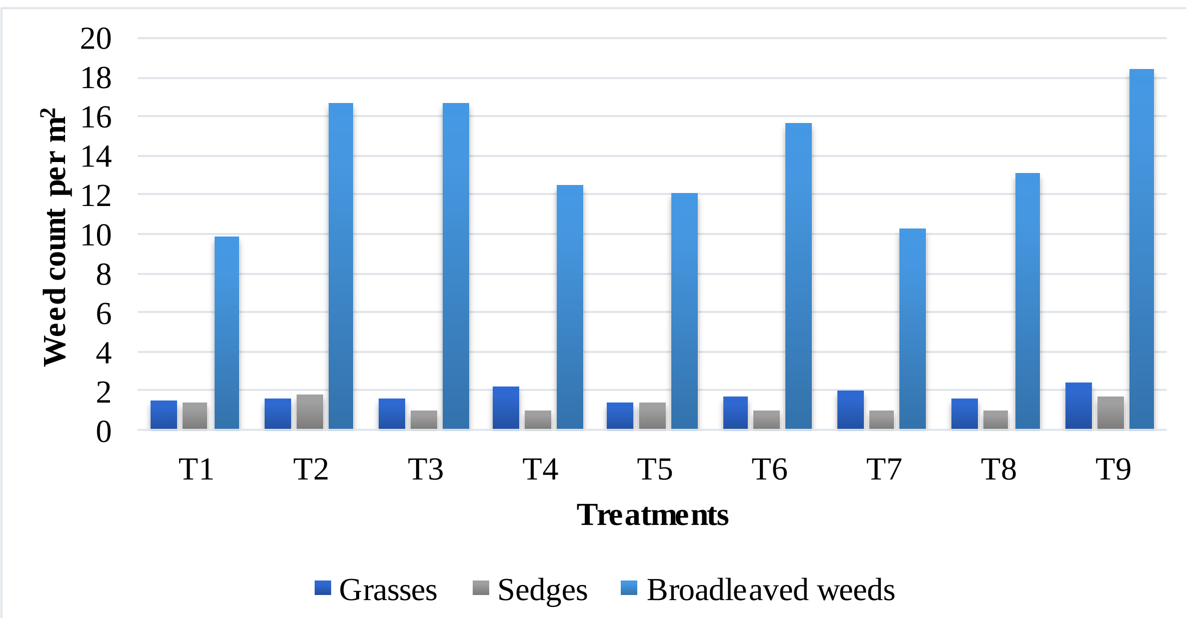

Fig. 4c. Effect of weed management on weed count per m^2 at 45 DAS

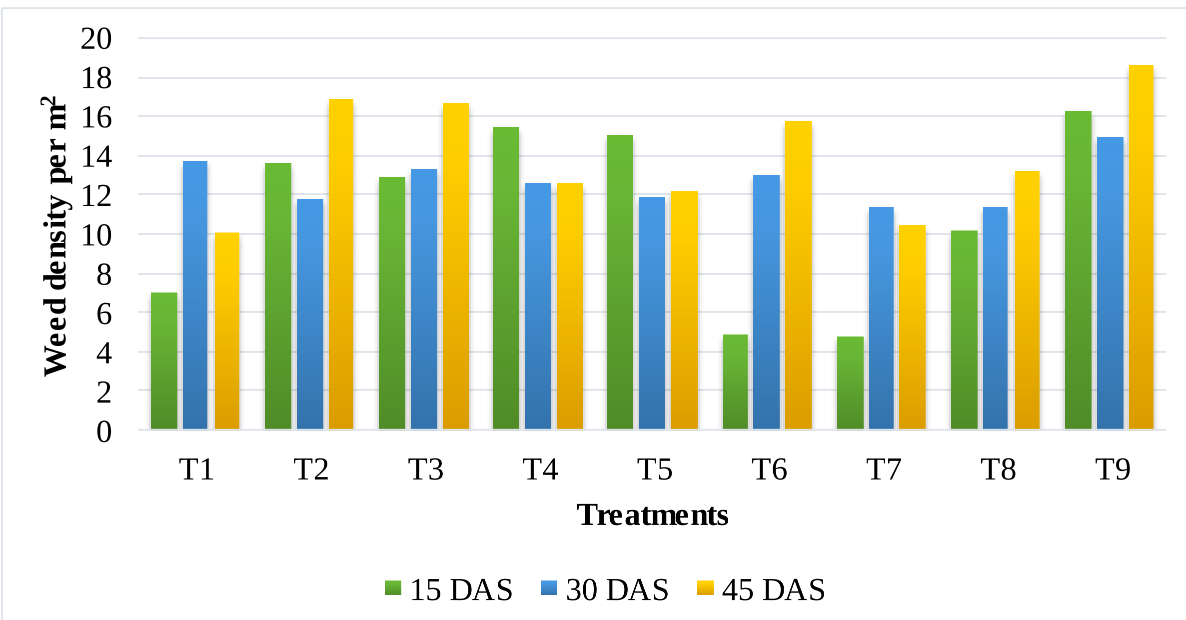

Fig. 5. Effect of weed management on weed density per m^2

The results clearly indicate that pre-emergent spray of pendimethalin without supplementary hand weeding at 30 DAS was incapable in controlling weed population at later stages of crop. The results revealed that all chemical, stale and hand weeding treatments reduced weed density over weedy check.

5.1.2. Effect of Weed Management on Weed Dry Weight and Weed Control Efficiency

During the initial period, less dry weight was observed in stale seed bed and in pre-emergence herbicide treatments due to lower weed population. At 30 DAS, hand weeding (T_8), imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) and imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS (T_3) and pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS (T_7) recorded lower weed biomass.

At 45 DAS, stale seed bed *fb* 1 hand weeding at 30 DAS (T_1) registered lower dry weight of weeds and was statistically comparable with T_3, T_5, T_7 and T_8 (Fig. 6). These treatments reduced the crop weed competition which had favoured crop growth and provided higher pod and haulm yield. The lowest yield was obtained in weedy check and it may be attributed to the highest weed dry weight and weed density. The higher total weed population, weed dry weight, weed index and lower weed control efficiency was recorded in weedy check. Goud *et al.* (2013), Lhungdim *et al.* (2013) and Lal *et al.* (2018) quoted similar findings.

This may be due to excellent control of broadleaved weeds, sedge and grassy weeds at critical stage of crop growth. These findings were in similar to those of Venkatesha *et al.* (2008), Devi *et al.* (2012) and Ram *et al.* (2013). At 15 DAS, the highest weed control efficiency (91.41 %) (Fig. 7) was recorded for pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS (T_7) and was on par with stale seed bed (T_1) and pendimethalin treatment (T_6). At 30 DAS, hand weeding treatment (T_8)

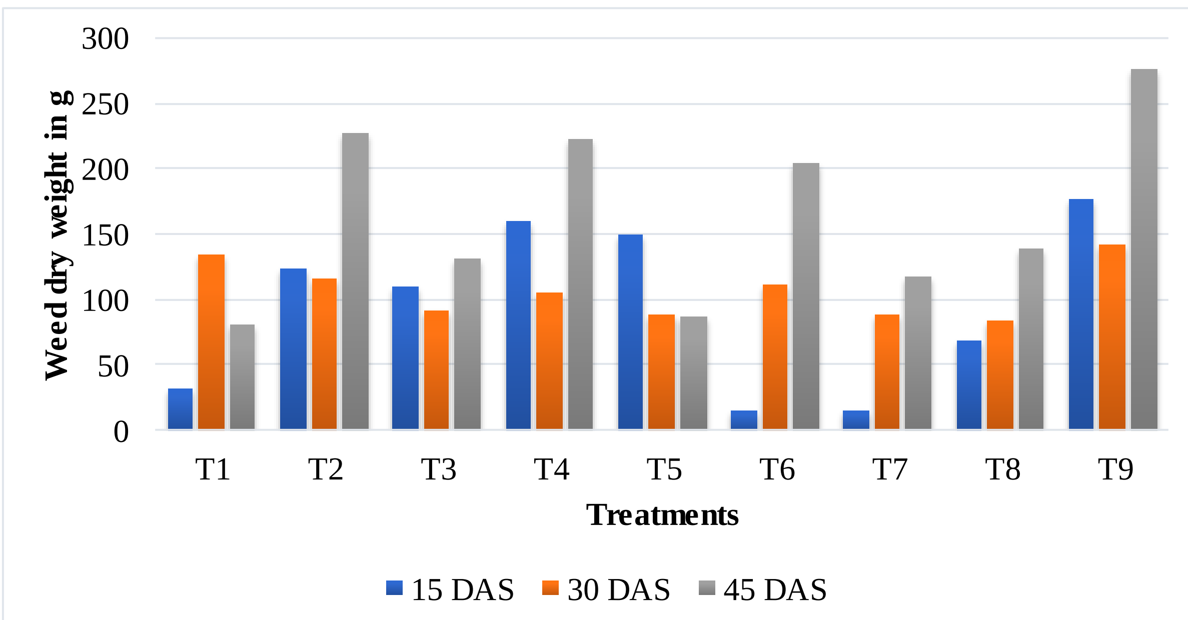

Fig. 6. Effect of weed management on weed dry weight per m^2

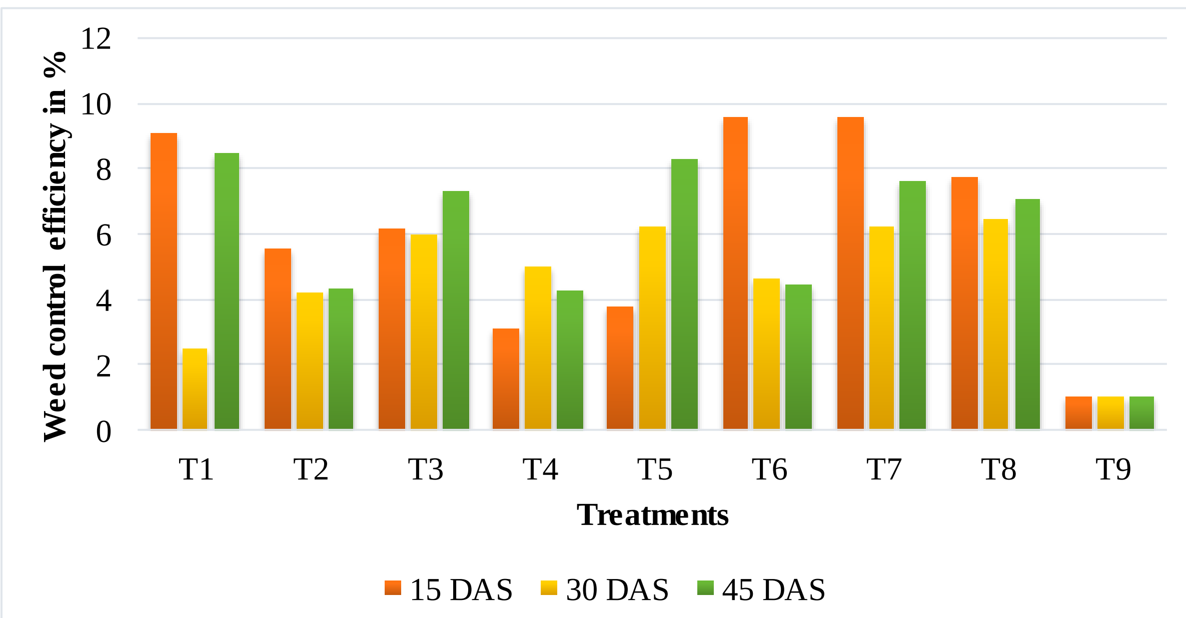

Fig. 7. Effect of weed management on weed control efficiency

registered the highest weed control efficiency (40.96 %) which was followed by T_5 (37.91 %), T_3, T_4 and T_7. At 45 DAS, stale seed bed *fb* hand weeding @ at 30 DAS (T_1) recorded the highest weed control efficiency (70.95 %), closely followed by imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) with a WCE of 68.44 per cent. Majumder (2009) reported that weeds should be controlled from 2 weeks after emergence and up to 50 days to avoid yield losses in groundnut. The critical weed competition period was from three to six week after sowing in groundnut (Priya *et al*., 2013). In this experiment imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) registered higher WCE at 30 and 45 days leading to reduced weed interference at the most critical stage of growth. The lowest value of WCE at all the stages, were recorded in unweeded check (T_9).

5.1.3. Effect of Weed Management on Weed Index

Negative value of weed index (-9.94 %) in imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) indicated the treatment's superiority over hand weeding treatment (T_8) (Fig. 8). The lowest weed index registered in T_5 may have resulted from the higher yield recorded under imazethapyr treatment. Better weed control resulted in reduced competition by weeds which paved the way for better availability and uptake of nutrients and resulted in higher yield. It remained statistically at par with stale seed bed *fb* 1 hand weeding at 30 DAS (T_1), imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS (T_3) and hand weeding twice (T_8). The highest weed index (46.83 %) was recorded for unweeded check (T_9). Season long crop-weed competition in unweeded check created significant impacts on the growth and yield characters and eventuated lowest yield and highest weed index.

5.2. EFFECT OF WEED MANAGEMENT ON GROWTH ATTRIBUTES OF GROUNDNUT

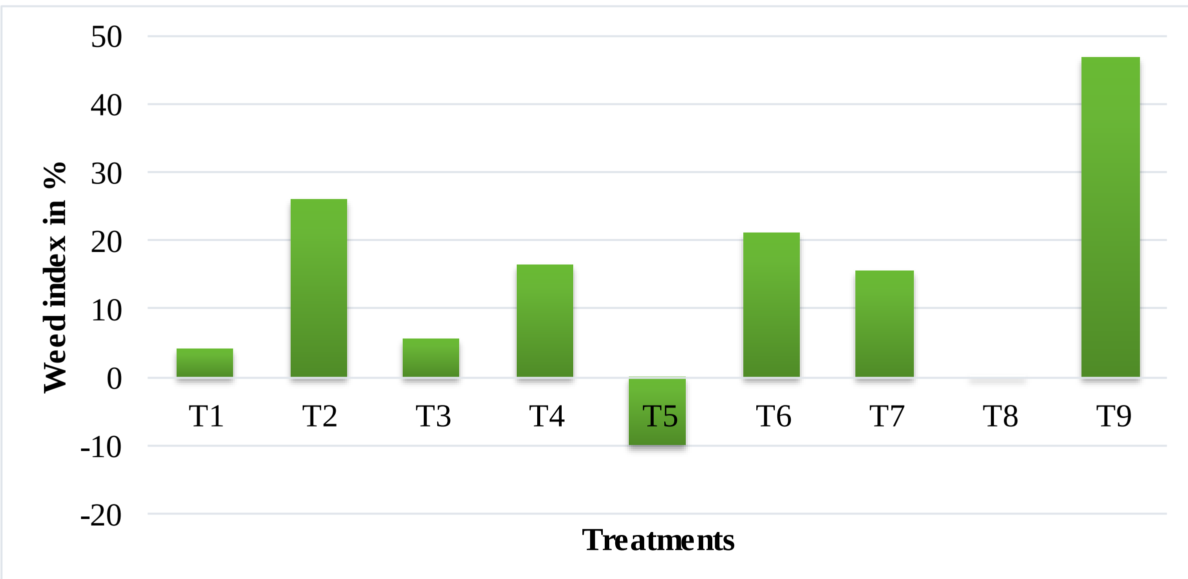

Fig. 8. Effect of weed management on weed index

Groundnut is extremely vulnerable towards weed competition owing to its sluggish growth in the early stages, dwarf stature and underground pod bearing habit. All growth attributes of groundnut were found the lowest throughout the growing period in untreated control due to higher weed density and the highest crop weed competition. Effective control of weeds is expected to have enhanced moisture availability, nutrients and solar radiation to plants, thereby increasing total chlorophyll content, photosynthetic rate and nitrate reductase activity (Channappagoudar *et al*., 2008), leading to higher supply of carbohydrates which resulted in higher increase in growth attributes than untreated control.

The different treatments employed for weed control in groundnut, exerted a significant influence on growth parameters like height of plant, number of branches per plant and leaf area, at every stage of crop growth (Fig. 9). During the early stages of growth, taller plants were observed with stale seed bed (T_1) and hand weeding treatment (T_8) due to early weed control effect. At harvest, higher plant height was recorded for imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) which was comparable with pendimethalin (PE) @ 1 kg ha^{-1} *fb* hand weeding at 30 DAS (T_7), hand weeding at 20 and 45 DAS (T_8) and stale seed bed *fb* 1 hand weeding at 30 DAS (T_1). Weeding twice had higher plant height due to efficient weed control (El Naim *et al*., 2010). The reasons that may be associated to such results are intense growth by plants in a weed free environment that ensured less competition for light, nutrients, and free space.

More number of branches per plant was noted in imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5), stale seed bed (T_1) and hand weeding treatment (T_8). It may be the result of severe plant growth thereby reducing the struggle of the crop for sunlight, nutrients, and available space in a weed free environment. The results indicated that weeds decreased the number of branches per plant. Yadava and Kurnar (1981) and Weiss (1983) commented that control of weeds in groundnut eventuated an increase in number of branches in comparison with unweeded plants.

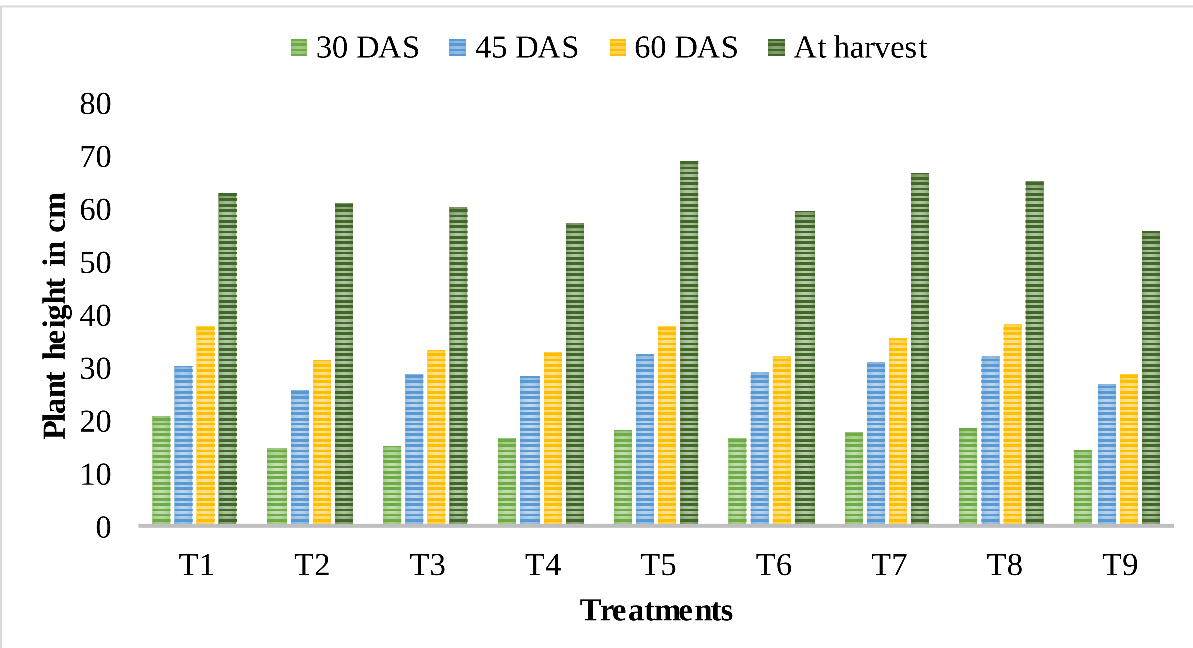

Fig. 9. Effect of weed management on plant height

On perusal of data, it was observed that leaf area increased from 30 DAS to 60 DAS and later declined towards harvest in every treatment. Among the herbicide treatments, the highest leaf area was found in imazethapyr @ 70 g ha^{-1} at 20 DAS (T_5) followed by imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS (T_3) and were statistically comparable with hand weeding (T_8) treatment. The higher leaf area might be due to proper allocation of resources for growth of leaves managing weeds and their competition with crop for resources. In weedy check, severe crop weed competition causes reduced leaf area at every growth stage. Similar findings were also documented by Bedry (2007) and Kumar (2009) in groundnut. They made the observation that the yield in terms of pods was remarkably escalated under treatments involving weeding, which in turn led to increased leaf area, more number of pods and branches per plant and finally maximum pod yield.

5.3. EFFECT OF WEED MANAGEMENT ON YIELD AND YIELD ATTRIBUTES

The weed management methods exerted a significant influence on yield contributing characters *viz.,* pod number per plant and 100 seed weight. The number of pods (Fig. 10) were higher in post-emergence application of imazethapyr @ 70 g ha^{-1} at 20 DAS (T_5), imazethapyr + imazamox (PoE) @ 80 g ha^{-1} (T_3) and pendimethalin (PE) *fb* hand weeding (T_7) that leads to higher seed yield in these treatments. The treatment effects were not significant in the case of number of seeds per pod. Higher 100 kernel weight (48.3 g) was recorded in post-emergence application of imazethapyr @ 70 g ha^{-1} at 20 DAS (T_5) which was on par with T_3, T_4, T_1 and T_7. The growth and yield attributes obtained at different growth stages of groundnut have revealed the influence of weed management on its productivity. Higher kernel yield (1652 kg ha^{-1}) was obtained from imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5), which was comparable with hand weeding treatment (T_8), imazethapyr + imazamox (PoE) @ 70 g ha^{-1} at 20 DAS (T_3) and stale seed bed *fb* 1 hand weeding at 30 DAS (T_1) (Fig. 11). Greater kernel yield may be due to reduction in density of weeds and biomass and higher weed control efficiency. The

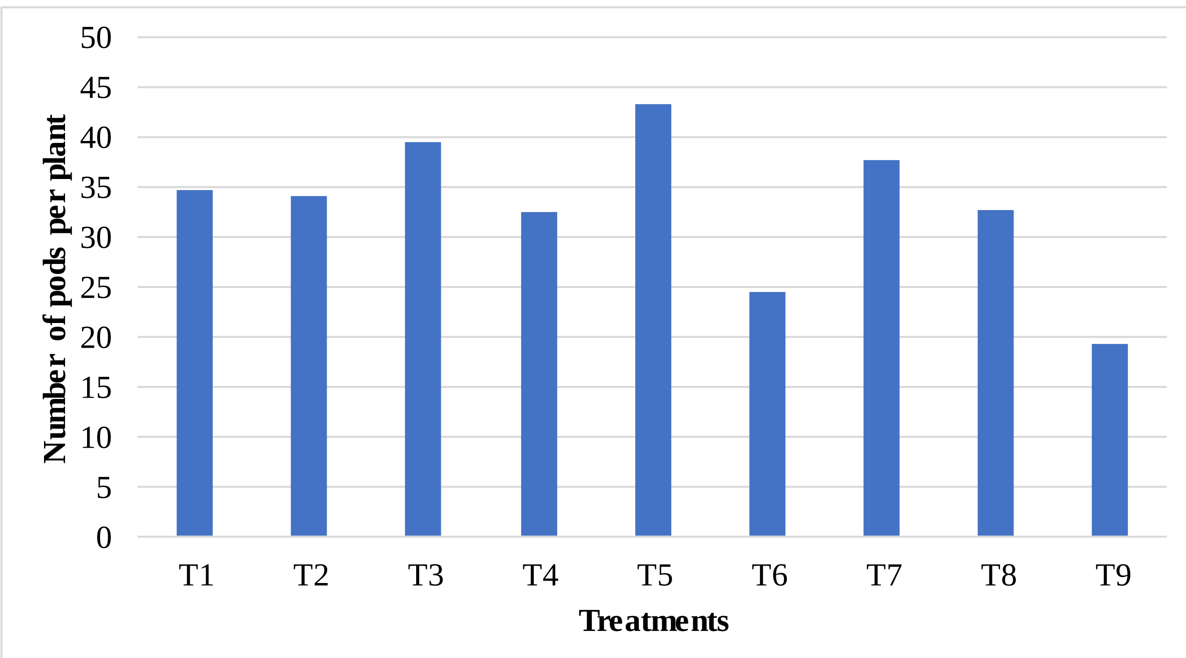

Fig. 10. Effect of weed management on number of pods per plant

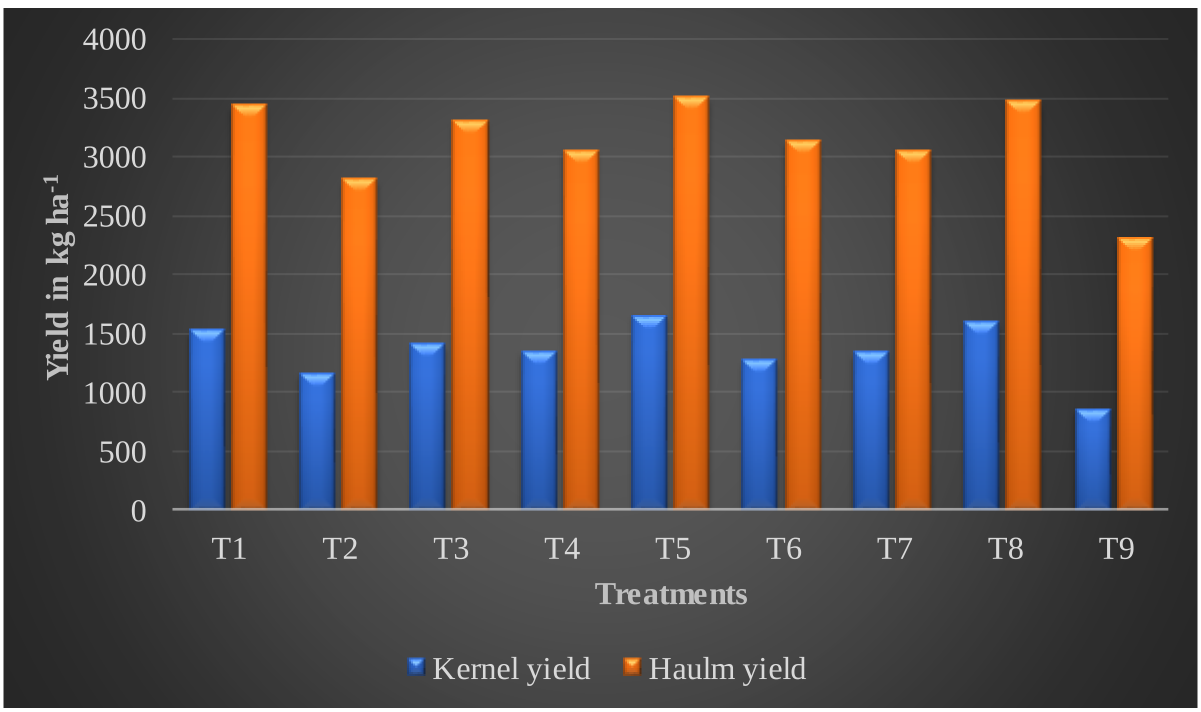

Fig. 11. Effect of weed management on kernel yield and haulm yield

percentage yield increase over weedy check in T_5, T_8 and T_1 were 93, 85 and 78 %, respectively (Fig. 12). The lowest yield (857 kg ha^{-1}) recorded was in unweeded check (T_9), which was inferior in comparison with other treatments.

Best treatment in terms of haulm yield (3502 kg ha^{-1}) was post-emergent spraying of imazethapyr @ 70 g ha^{-1} at 20 DAS (T_5) which remained statistically at par with all the treatments except T_9 and T_2. Lower haulm yield (2300 kg ha^{-1}) was observed in unweeded check (T_9). Higher harvest index (0.393) was registered in imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) which was on par with all the treatments except imazethapyr + imazamox @ 40 g ha^{-1} (T_2) and unweeded check (T_9). Imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) documented the higher shelling percentage (72.95) which was on par with stale seed bed *fb* 1 hand weeding at 30 DAS (T_1), post-emergence applications (T_2 and T_4), pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS (T_7) and hand weeding at 20 DAS and 45 DAS (T_8). This may be due to higher kernel yield obtained in these treatments.

5.4. EFFECT OF WEED MANAGEMENT ON NUTRIENT UPTAKE

5.4.1. Nutrient Uptake by Crop

The nutrient removal by plant is a function of nutrient content and dry matter production of the plant. The higher values of nutrient content and dry matter production resulted in increased uptake values. This was the result of less crop-weed competition during critical stages for the essential nutrients, leading to its enhanced removal. The results revealed that N and P uptake were higher in post-emergence application of imazethapyr @ 70 g ha^{-1} at 20 DAS (T_5), pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS (T_7) and hand weeding at 20 and 45 DAS (T_8). Higher K uptake (83.53 kg ha^{-1}) was registered under imazethapyr applied as post-emergence @ 70 g ha^{-1} at 20 DAS (T_5), which was comparable with T_4, T_6 and T_7. This may be due to the

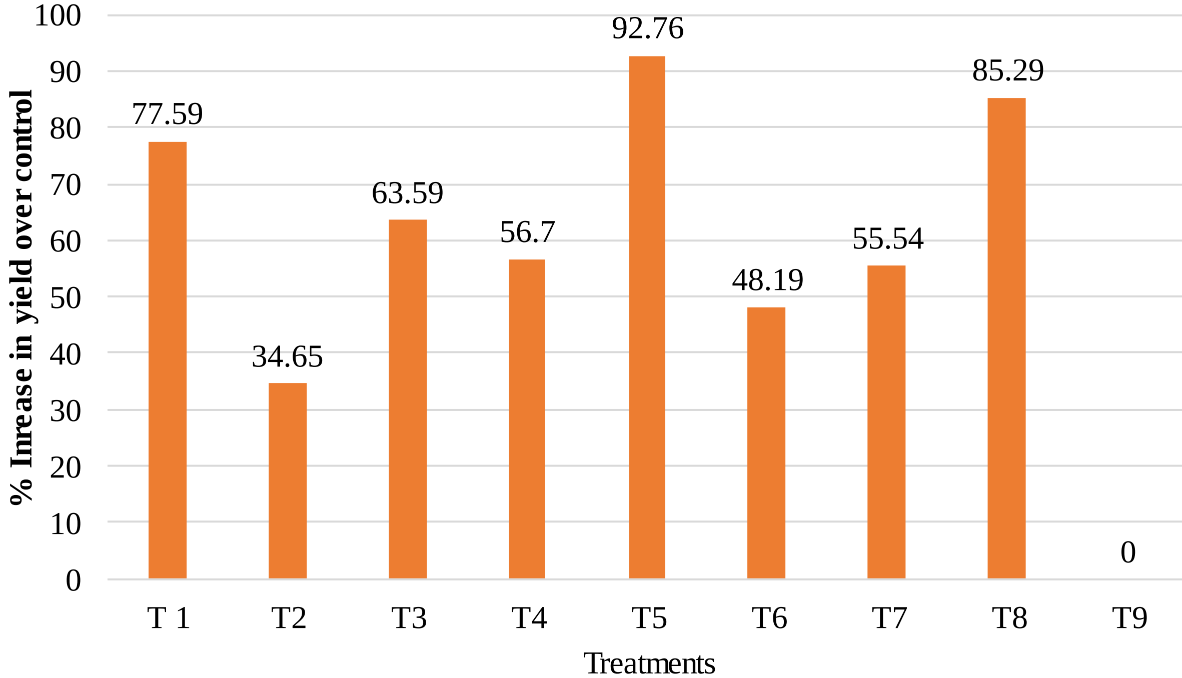

Fig. 12. Percentage increase in yield over control plot

reduction in weed density and weed dry matter production in these treatments. On the contrary, the lowest crop nutrient uptake was noticed in unweeded check due to increased competition between crop and weeds. These results were similar to the findings of Chandolia *et al*. (2010) who concluded that the highest nitrogen and phosphorus uptake by groundnut were documented under hand weeding treatment and chemical control plots in comparison with those in untreated plot.

5.4.2. Nutrient Removal by Weeds at Flowering Stage

The nutrient removal by weeds (N, P and K uptake) at flowering stage were influenced by weed management (Fig. 13). Weeds are very competitive in extracting plant nutrients from the soil. Jat *et al*. (2011) opined that weeds remove 2 and 24 times more N and K than groundnut crop. The results revealed that nitrogen removal (1.84 kg ha^{-1}) by weeds was lower in stale seed bed *fb* 1 hand weeding at 30 DAS (T_1) and post-emergent sprays of imazethapyr (T_4 and T_5), pendimethalin (PE) *fb* 1 hand weeding at 30 DAS (T_7) and hand weeding at 20 and 45 DAS (T_8). This was due to the effect of cultural practices and weed control efficiency of herbicides for controlling weed population and thereby the weed dry weight. Higher nitrogen removal by weeds (6.29 kg ha^{-1}) was noted in unweeded check (T_9) due to the increased dry matter production.

Lower P uptake (0.18 kg ha^{-1}) was recorded in stale seed bed *fb* 1 hand weeding at 30 DAS (T_1) which was on par with T_4, T_5, T_7 and T_8. K removal by weeds (1.47 kg ha^{-1}) was lower in pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS (T_7) and remained statistically at par with T_4, T_5, T_8 and T_1. Unweeded check (T_9) documented higher uptake of N, P and K because of the high weed population and dry weight.

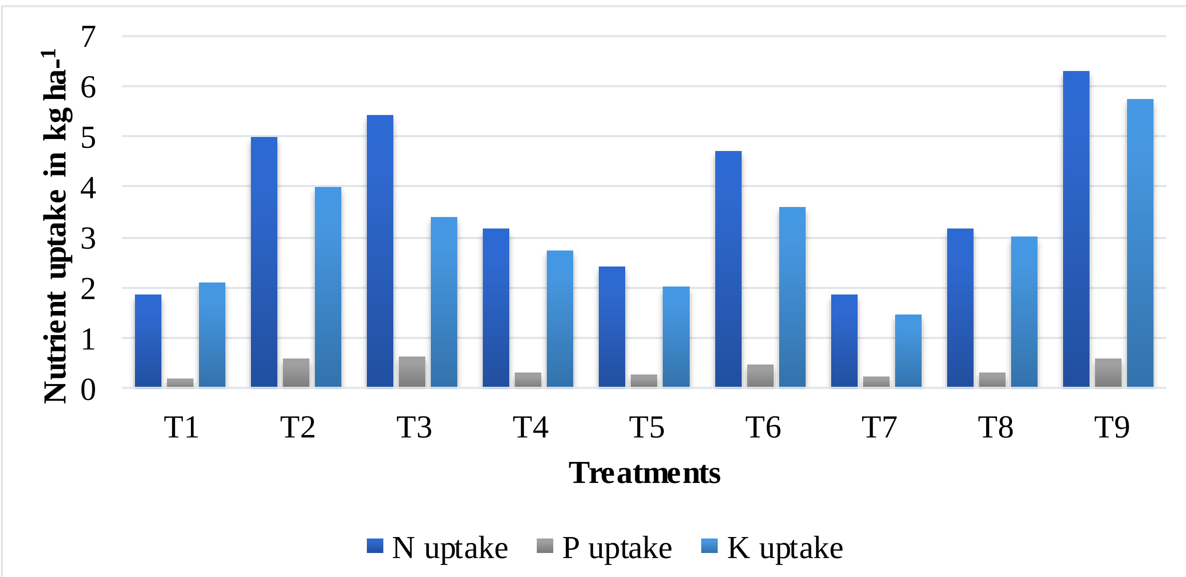

Fig. 13. Effect of weed management on nutrient removal by weeds at flowering stage

5.5. EFFECT OF WEED MANAGEMENT ON SOIL FERTILITY STATUS AFTER THE EXPERIMENT

The different weed management treatments did not produce any difference with respect to soil reaction, electrical conductivity and organic carbon content. The pH of site increased to a near neutral level due to uniform lime application. The available nitrogen status was low before and after the experiment. The initial and final status of K also remained as medium. The P status changed from medium to high after the experiment. The available N status was influenced by the treatments. However weed management treatments did not have any influence on available P and K after the experiment.

Higher available N (255.06 kg ha^{-1}) was recorded for hand weeding at 20 and 45 DAS (T_8), and was comparable with post-emergence application of imazethapyr (T_4), stale seed bed (T_1), pre-emergence treatments (T_6 and T_7) and unweeded check (T_9). Higher availability of N in hand weeding and herbicides may be due to enhanced N fixation by the crop and in unweeded check it may due to lower uptake of N by the crop (Fig. 14). Low available N (194.43 kg ha^{-1}) was recorded in imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS (T_2), which was comparable with post-emergence treatments (T_3 and T_5). Higher nitrogen uptake by crop could be the potential reason for this. Pendimethalin and imazethapyr applications at the recommended and double the recommended doses did not adversely influence the physical, physico-chemical and fertility properties of soil (Sudharshana, 2012).

5.6. EFFECT OF WEED MANAGEMENT ON ECONOMICS

The economics of the present study are graphically illustrated in Fig. 15a, 15b. The results showed that the economics of groundnut was influenced by the weed management. The economic analysis also showed the same trend as that of kernel yield of groundnut. The economic analysis of data revealed that less cost of cultivation

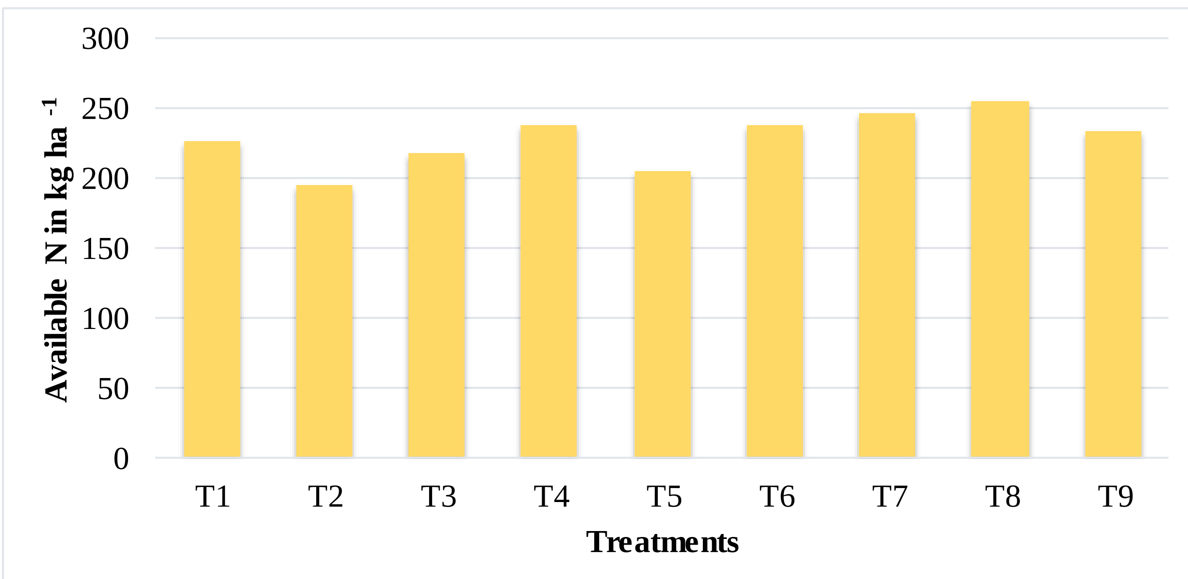

Fig. 14. Effect of weed management on soil available N status after the experiment

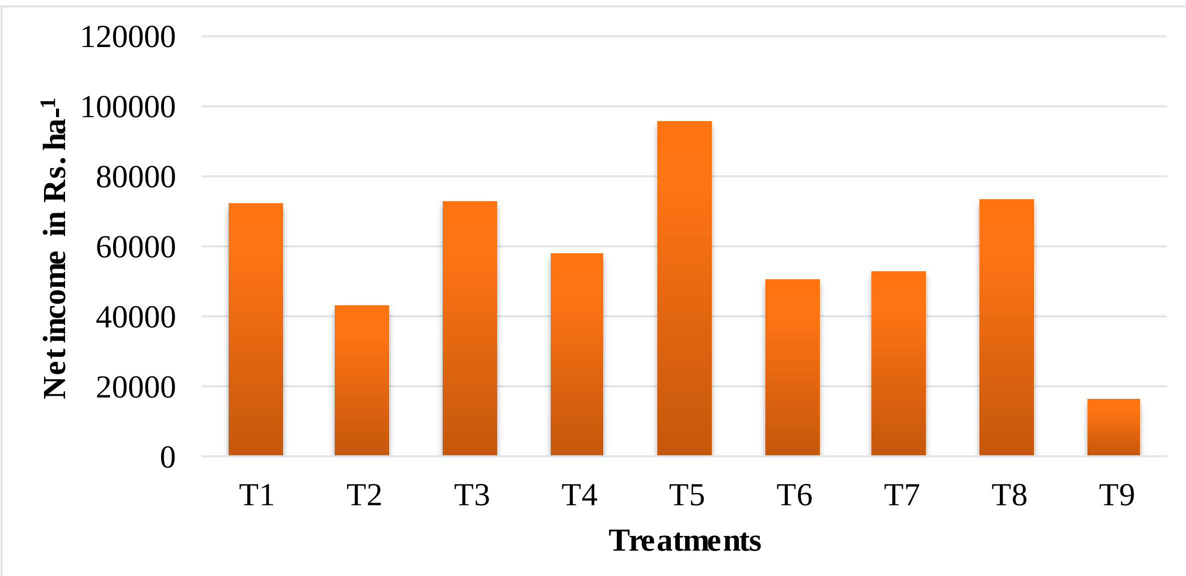

Fig. 15a. Effect of weed management on net income

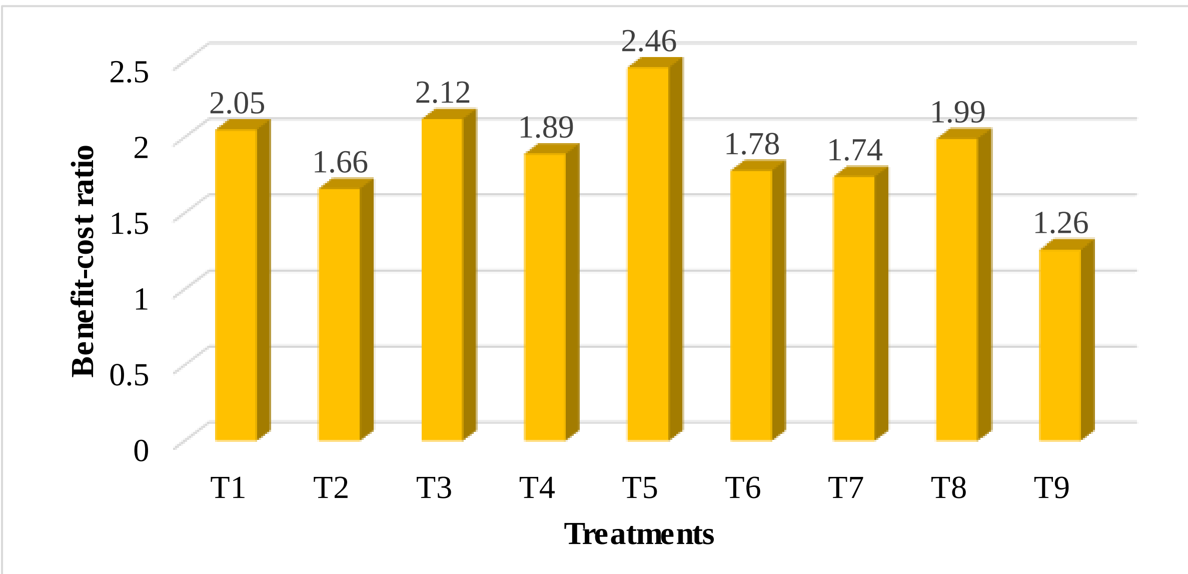

Fig. 15b. Effect of weed management on benefit-cost ratio

from the herbicide treatments due to savage of labour when compared to hand weeding and stale seed bed technique.

The highest net income (Rs. 95611) was obtained from post-emergent application of imazethapyr @ 70 g ha^{-1} at 20 DAS (T_5) and was subsequently followed by hand weeding and stale seed bed treatments. The BCR (2.46) was higher for imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) followed by imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS (2.12) (T_3) and stale seed bed *fb* 1 hand weeding at 30 DAS (2.05) (T_1), respectively. The lowest BCR (1.26) was for unweeded check (T_9). The variations in BCR could be a consequence of the cost of cultivation and gross return. The high BCR in T_5 and T_3 was due to the less cost of cultivation. Treatments involving hand weeding, did considerably reduce the weed dry weight and enhanced the kernel yield, yet were only able to produce low benefit-cost ratio because of high labour costs. The findings are in confirmity with the results of Tamang *et al.* (2015). Kausar *et al.* (2019) opined that eventhough hoeing by hand was able to produce reasonable yield, it was not feasible considering the economic aspects, due to high labor charges. Therefore on concluding, it can be said that application of weedicides is the most suitable and economical practice for weed management in summer groundnut.

Summary

6. SUMMARY

The field experiment entitled "Weed management in summer groundnut (*Arachis hypogaea* L.)" was taken up with the objectives to find out the best weed management option for the summer groundnut in the *Onattukara* tract and to compute the economics of cultivation. The experiment was carried out from December 2019 to April 2020 in farmer's field at Vallikunnam panchayath in the *Onattukara* region of Alappuzha district.

The experimental lay out was carried out in randomized block design with 9 treatments and 3 replications. The treatments were T_1 - stale seed bed *fb* 1 hand weeding at 30 DAS; T_2 - imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS; T_3 - imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS; T_4 - imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS; T_5 - imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS; T_6 - pendimethalin (PE) @ 1.0 kg ha^{-1}; T_7 - pendimethalin (PE) @ 1.0 kg ha^{-1} *fb* hand weeding at 30 DAS; T_8 – hand weeding at 20 DAS and 45 DAS; T_9 – unweeded check. FYM @ 2 t ha^{-1}, N: P_2O_5: K_2O @ 10:75:75 kg ha^{-1} (as basal) and lime 1.5 t ha^{-1} (at flowering) were applied uniformly to all treatments. The bunch type groundnut variety, CO7 was sown at a spacing of 15 cm x 15 cm. The experimental results are summarized below.

The growth parameters of groundnut were documented at 30, 45 and 60 DAS and at harvest. At all stages the growth parameters varied significantly with the weed management treatments. At 45, 60 DAS and at harvest taller plants (32.48 cm, 37.67 cm and 69 cm, respectively) were observed with imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) and was comparable with hand weeding at 20 and 45 DAS (T_8), pendimethalin (PE) @ 1 kg ha^{-1} *fb* hand weeding at 30 DAS (T_7) and stale seed bed *fb* 1 hand weeding at 30 DAS (T_1).

At all growth stages, imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) registered higher number of branches (6.33, 6.57, 6.77 and 6.97, respectively) and was on par with stale seed bed *fb* 1 hand weeding at 30 DAS (T_1), and hand weeding at 20 and 45 DAS (T_8).

At 30 and 45 DAS, pendimethalin (PE) @ 1 kg ha^{-1} *fb* hand weeding at 30 DAS (T_7) recorded higher leaf area per plant (376.91 cm^2 and 684.19 cm^2, respectively). At 60 DAS and at harvest, imazethapyr @ 70 g ha^{-1} at 20 DAS (T_5) documented higher leaf area per plant (1114.33 cm^2 and 926.58 cm^2, respectively), and was on par with imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS (T_3) and hand weeding at 20 and 45 DAS (T_8).

The various treatments employed for weed management had a significant influence on the yield parameters *viz.*, days to 50 per cent flowering, number of pods per plant, 100 kernel weight, kernel yield, haulm yield, harvest index and shelling percentage. Imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS (T_4) took lesser days (38) to complete 50 per cent flowering in comparison with other treatments, and stayed statistically at par with T_7 and T_9. The number of pods and 100 kernel weight were higher (43.20 and 48.30 g, respectively) in imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) and it was on par with imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS (T_3) and pendimethalin (PE) @ 1 kg ha^{-1} *fb* hand weeding at 30 DAS (T_7). With respect to 100 kernel weight, T_5 also remained statistically at par with T_1 and T_4.

Higher kernel yield and haulm yield (1652 and 3502 kg ha^{-1}, respectively) was attained from imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5). With respect to kernel yield T_5 was comparable with hand weeding at 20 and 45 DAS (T_8) (1588 kg ha^{-1}), imazethapyr + imazamox (PoE) @ 70 g ha^{-1} at 20 DAS (T_3) (1402 kg ha^{-1}) and stale seed bed *fb* 1 hand weeding at 30 DAS (T_1) (1522 kg ha^{-1}). T_5 remained statistically at par with all the other treatments except T_9 and T_2, in the case of haulm yield. Higher harvest index (0.393) was recorded in imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) which was statistically comparable with all the treatments except T_2 and T_9. Imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) registered higher shelling percentage (72.95) which was on par with stale seed bed *fb* 1 hand weeding at 30 DAS (T_1) (71.82), imazethapyr + imazamox (PoE) @ 40 g ha^{-1} (T_2) (69.28), imazethapyr @ 37.5 g ha^{-1} at 20 DAS (T_4) (69.27), pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS (T_7) (70.79) and hand weeding at 20 DAS and 45 DAS (T_8) (71.15). The results revealed that the treatment effects were not significant with respect to number of seeds per pod.

The predominant weed flora observed was broadleaved weeds and *Portulaca oleraceae* was the most dominant weed species. Other broadleaved weeds were *Cleome rutidosperma, Melochia corchorifolia, Synedrella nodiflora, Phyllanthus niruri, Heliotropium indicum.* There were only two grassy weeds, *Cynodon dactylon* and *Eleusine indica. Cyperus rotundus* was the only sedge noted in the investigational plots. Weed parameters *viz.,* weed count per m^2, weed density per m^2, weed dry weight and weed control efficiency were recorded at 15, 30 and 45 DAS. At 15 and 30 DAS, grassy weeds were lower (1.33) in imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5), pendimethalin (PE) @ 1 kg ha^{-1} (T_6), pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS (T_7) and hand weeding at 20 DAS and 45 DAS (T_8). At 45 DAS, the weed management treatments did not exert any significant influence on the population of grassy weeds. The influence of the weed management treatments on number of sedges was insignificant. Pendimethalin (PE) @ 1 kg ha^{-1} *fb* hand weeding at 30 DAS (T_7) recorded lower broadleaved weeds (20.33 and 121.66) at 15 and 30 DAS, respectively. At 45 DAS, stale seed bed *fb* 1 hand weeding at 30 DAS (T_1) recorded lower population of broadleaved weeds (96.00) which remained statistically at par with T_7 (105.00) and T_5 (145.33).

At 15 DAS, pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS (T_7) recorded lower weed density per m^2 (22.22) which was on par with pendimethalin (PE) @ 1 kg ha^{-1} (T_6) (23.23). At 30 DAS, hand weeding at 20 and 45 DAS (T_8) recorded lower weed density (127.89) and was on par with imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS (T_2) (139.20), imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) (141.67) and pendimethalin (PE) @ 1 kg ha^{-1} *fb* hand weeding (T_7) (128.00). At 45 DAS, stale seed bed *fb* 1 hand weeding at 30 DAS (T_1) recorded lower weeds density per m^2 (100.00) and was statistically comparable with imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) (147.08) and pendimethalin (PE) @ 1 kg ha^{-1} *fb* hand weeding at 30 DAS (T_7) (109.17). At 15 DAS, pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS (T_7) recorded lower weed dry weight (14.67 g) compared to every other treatments and was comparable with stale seed bed *fb* 1 hand weeding at 30 DAS (T_1) (32.00 g) and pendimethalin (PE) @ 1 kg ha^{-1} (T_6) (15.33 g). At 30 DAS, less weed dry weight (83.75 g) was documented in hand weeding at 20 and 45 DAS (T_8) and was comparable to imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS (T_3) (91.87 g), imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) (87.37 g) and pendimethalin (PE) @ 1 kg ha^{-1} *fb* hand weeding (T_7) (88.44 g). Stale seed bed *fb* 1 hand weeding at 30 DAS (T_1) documented less weed dry weight at 45 DAS (80 g), which stayed statistically at par with imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS (T_3) (130.67 g), imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) (87.33 g), pendimethalin (PE) *fb* hand weeding at 30 DAS (T_7) (117.67 g) and hand weeding at 20 and 45 DAS (T_8) (138.67 g).

At 15 DAS, the highest weed control efficiency (91.41 %) was registered under pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS (T_7) and was on par with T_1 (81.68 %) and T_6 (90.76 %). At 30 DAS, hand weeding at 20 and 45 DAS (T_8) documented highest weed control efficiency (40.96 %), subsequently followed by T_5 (37.91 %), T_3 (34.84 %), T_4 (25.38 %) and T_7 (37.57 %), respectively. At 45 DAS, stale seed bed *fb* hand weeding @ at 30 DAS (T_1) recorded the highest WCE (70.95 %), closely followed by T_5 (68.44 %), T_3 (52.90 %), T_7 (57.35 %) and T_8 (49.54 %), respectively.

The nutrient removal by weeds was recorded at flowering stage. The results revealed that weed uptake of N and P was lower in stale seed bed *fb* 1 hand weeding at 30 DAS (T_1) (1.84 kg ha^{-1} and 0.18 kg ha^{-1}, respectively), followed by imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS (T_4) (3.17 kg ha^{-1} and 0.31 kg ha^{-1} respectively) and imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) (2.40 kg ha^{-1} and 0.27 kg ha^{-1} respectively), pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS (T_7) (1.87 kg ha^{-1} and 0.22 kg ha^{-1}, respectively) and hand weeding at 20 and 45 DAS (T_8) (3.17 kg ha^{-1} and 0.31 kg ha^{-1} respectively). K uptake by weeds (1.47 kg ha^{-1}) was lower in pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS (T_7), and was comparable with imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS (T_4), imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5), hand weeding at 20 and 45 DAS (T_8) and stale seed bed *fb* 1 hand weeding at 30 DAS (T_1).

The weed index ranged from -9.94 to 46.83 per cent over the treatments. Negative value of weed index (-9.94 %) in imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) indicates that it was superior to the hand weeding treatment (T_8). It remained statistically at par with stale seed bed *fb* 1 hand weeding at 30 DAS (T_1) (4.02 %) and imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS (T_3) (5.62 %).

The results revealed that plant uptake of N, P and K at harvest was higher in imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) (173.00 kg ha^{-1}, 16.36 kg ha^{-1} and 83.53 kg ha^{-1}, respectively) and was on par with T_7 (152.92 kg ha^{-1}, 16.32 kg ha^{-1} and 72.54 kg ha^{-1}, respectively) and T_8 (151.44 kg ha^{-1}, 14.08 kg ha^{-1} and 54.87 kg ha^{-1}, respectively). T_5 was also comparable with T_4 (69.15 kg ha^{-1}) and T_6 (76.15 kg ha^{-1}) with respect to K uptake.

Soil samples after the experiment were analyzed for pH, electrical conductivity, organic carbon content, available nitrogen, phosphorus and potassium status and results exhibited significant treatment effects only with respect to available N. Higher available N (255.06 kg ha^{-1}) was documented for the treatment hand weeding at 20 and 45 DAS

(T_8), and was comparable with imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS (T_4) (238.34 kg ha^{-1}), stale seed bed *fb* 1 hand weeding at 30 DAS (T_1) (225.79 kg ha^{-1}), pendimethalin (PE) @ 1 kg ha^{-1} (T_6) (238.34 kg ha^{-1}), pendimethalin (PE) @ 1 kg ha^{-1} *fb* 1 hand weeding at 30 DAS (T_7) (246.70 kg ha^{-1}) and unweeded check (T_9) (234.16 kg ha^{-1}).

No major pest and diseases were observed in the field during the crop period.

The highest net income (₹ 95611) was recorded for imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5) followed by hand weeding at 20 and 45 DAS (T_8) (₹ 73079) and imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS (T_3) (₹ 72794). The B-C ratio (2.46) was higher in imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS (T_5). T_5 was closely followed by T_3 (post-emergence application of imazethapyr + imazamox @ 80 g ha^{-1} at 20 DAS) and T_1 (stale seed bed *fb* 1 hand weeding at 30 DAS) with a B-C ratio of 2.12 and 2.05, respectively.

Thus, on successful completion of the experiment, the conclusion that can be drawn is that post emergence application of imazethapyr @ 70 g ha^{-1} at 20 DAS (T_5) is the effectual practice of weed management for summer groundnut in *Onattukara* tract considering the growth, yield and economics.

Future Line of Work

- Herbicide residue analysis in soil and plant is to be executed to determine the chance of entry of the herbicides into the agro ecosystem.
- There is also a need to study the potentiality of development of herbicide resistance in weeds.

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Appendices

APPENDIX - I

Standard weeks	Rainfall (mm)	Temperature (°C)		Relative Humidity (%)	
		Maximum	Minimum	Maximum	Minimum
52	0.0	35.0	21.1	87.6	75.9
1	0.2	34.6	21.9	85.3	74.6
2	0.0	34.9	21.0	79.0	62.7
3	0.0	34.9	21.3	79.7	62.9
4	0.0	36.4	19.9	83.1	66.1
5	0.0	36.0	20.4	78.6	62.9
6	0.0	36.0	21.7	72.6	61.6
7	0.0	34.9	22.1	75.1	64.6
8	0.0	35.6	21.4	80.6	65.1
9	22.0	36.0	21.0	86.4	64.9
10	0.0	36.0	20.4	86.0	70.6
11	1.4	36.1	19.6	76.7	68.3
12	7.6	36.9	20.1	79.6	69.0
13	10.0	32.9	24.7	73.7	64.7
14	12.6	34.3	24.7	71.3	62.9
15	1.2	34.6	25.0	70.6	66.7

WEED MANAGEMENT IN SUMMER GROUNDNUT
(*Arachis hypogaea* L.)

by

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ABSTRACT

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ABSTRACT

A field experiment on "Weed management in summer groundnut (*Arachis hypogaea* L.)" was undertaken during 2018-20 with the objectives to find out the best weed management option for the summer groundnut in the *Onattukara* tract and to work out the economics of cultivation. The experiment was carried out from December 2019 to April 2020 in farmer's field at Vallikunnam Panchayath in the *Onattukara* region of Alappuzha district.

The experiment was laid out in randomized block design with 9 treatments replicated thrice. The treatments were T_1 - stale seed bed *fb* 1 hand weeding at 30 DAS; T_2 - imazethapyr + imazamox (PoE) @ 40 g ha^{-1} at 20 DAS; T_3 - imazethapyr + imazamox (PoE) @ 80 g ha^{-1} at 20 DAS; T_4 - imazethapyr (PoE) @ 37.5 g ha^{-1} at 20 DAS; T_5 - imazethapyr (PoE) @ 70 g ha^{-1} at 20 DAS; T_6 - pendimethalin (PE) @ 1.0 kg ha^{-1}; T_7 - pendimethalin (PE) @ 1.0 kg ha^{-1} *fb* hand weeding at 30 DAS; T_8 – hand weeding at 20 DAS and 45 DAS; T_9 – unweeded check. FYM @ 2 t ha^{-1}, N: P_2O_5: K_2O @ 10:75:75 kg ha^{-1} (as basal) and lime 1.5 t ha^{-1} (at flowering) were applied uniformly to all treatments. The bunch type groundnut variety, CO7 was sown at a spacing of 15 cm x 15 cm.

The growth characters, *viz*., plant height, number of branches and leaf area were recorded at 30, 45, 60 DAS and at harvest. The plant height was higher in T_5 at all growth stages except at 30 DAS. Number of branches was higher in T_5 which was on par with T_1 at all growth stages. The leaf area per plant was higher in T_3 and T_5 at 60 DAS and at harvest. Higher 100 kernel weight was observed in T_5 (48.3 g) which was on par with T_1, T_3, T_4 and T_7. The number of pods per plant was higher for T_5 (43.2) which was on par with T_3 and T_7. The treatment T_5 recorded higher kernel yield (1652 kg ha^{-1}) and haulm yield (3502 kg ha^{-1}) and was on par with T_8, T_1 and T_3 for kernel yield and with all treatments except T_2 and T_9 for haulm yield. Harvest index of T_5 (0.393) was on par with all treatments except T_2 and T_9. The shelling percentage was recorded higher in T_5 (72.95) which was on par with T_4, T_2, T_7, T_1 and T_8.

The predominant weed flora of the experimental field was broadleaved weeds followed by grasses and sedge. Lower weed density and dry weight at early stage were recorded in pre emergence application treatments (T_6 and T_7). At 30 DAS, treatments T_8, T_7, T_5 and at 45 DAS, T_1, T_5 and T_7, respectively recorded lower weed density and dry weight. Nutrient removal by weeds at flowering was also influenced by the treatments. The WCE was the highest in T_7 (91.41%) at 15 DAS, T_8 (40.96%) and T_5 (37.91%) at 30 DAS and T_1 (70.95%) and T_5 (68.44%) at 45 DAS. Negative value of weed index in T_5 (-9.94 %) indicated the superiority of T_5 over hand weeding treatment (T_8).

Plant N, P, K uptake was higher in T_5 (post-emergence application of imazethapyr @ 70 g ha^{-1} at 20 DAS). The chemical properties of soil were not influenced by the treatments except available nitrogen content which was recorded higher in T_8 and was on par with T_1, T_4, T_6, T_7 and T_9. No serious pest and diseases were observed during the study. T_5 recorded the highest net income and B-C ratio (₹ 95611 and 2.46, respectively). It was followed by T_3 which recorded a BCR of 2.12.

The results of the study revealed that post-emergence application of imazethapyr @ 70 g ha^{-1} at 20 DAS (T_5) is the effective weed management practice for summer groundnut in *Onattukara* considering the growth, yield and economics.

സംഗ്രഹം

“വേനൽക്കാല നിലക്കടലയിലെ കള നിയന്ത്രണം” എന്ന വിഷയത്തെ ആസ്പദമാക്കി ഒരു ഗവേഷണ പഠനം 2018 – 2020 കാലഘട്ടത്തിൽ വെള്ളായണി കാർഷിക കോളേജിലും ഓണാട്ടുകര വേനൽക്കാല തരിശുനിലത്തിലുമായി നടത്തുകയുണ്ടായി. വേനൽക്കാലത്തെ നിലക്കടല കൃഷിക്ക് ഏറ്റവും അനുയോജ്യവുമായ കള നിയന്ത്രണ രീതിയും അതിന്റെ വരവ് ചെലവകളും കണക്കാക്കുക എന്നതായിരുന്നു പഠനത്തിന്റെ ലക്ഷ്യം.

റാൻഡമൈസ്ഡ് ബ്ലോക്ക് ഡിസൈൻ എന്ന സാംഖ്യ ക്രിയാ രീതിയിൽ 9 ട്രീട്മെന്റുകൾ മൂന്ന് തവണ ആവർത്തിച്ചാണ് പരീക്ഷണം നടത്തിയത്. തമിഴ് നാട് കാർഷിക സർവകലാശാലയുടെ CO7 എന്ന വിത്തും, കേരള കാർഷിക സർവകലാശാലയുടെ വളപ്രയോഗ ശുപാർശകളുമാണ് പരീക്ഷണത്തിന് ഉപയോഗിച്ചത്. കള നിയന്ത്രണത്തിനായി ഉപയോഗിച്ച ട്രീട്മെന്റുകളും അവയുടെ അളവുകളും താഴെ കൊടുത്തിരിക്കുന്നു.

കളയ്ക്ക് കിളിപ്പിക്കലിന് പുറമേ മുപ്പതാം ദിവസം നൽകുന്ന കൈകൊണ്ടുള്ള കളപറിക്കൽ; ഒരു ഹെക്ടറിനു 40, 80 ഗ്രാം എന്നീ അളവുകളിൽ ഇരുപതാം ദിവസം നൽകുന്ന ഇമസെത്താപൈർ + ഇമസാമോക്സ് എന്ന മിശ്രിത കളനാശിനിയുടെ പ്രയോഗം; ഒരു ഹെക്ടറിനു 37.5, 70 ഗ്രാം എന്നീ അളവുകളിൽ ഇരുപതാം ദിവസം നൽകുന്ന

ഇമസെത്താപൈർ എന്ന കളനാശിനിയുടെ പ്രയോഗം; ഒരു ഹെക്ടറിനു 1 കിലോഗ്രാം എന്ന അളവിൽ, നട്ട് 2-3 ദിവസത്തിനുള്ളിൽ നൽകുന്ന പെന്റിമെത്താലിൻ എന്ന കളനാശിനിയുടെ പ്രയോഗം; പെന്റിമെത്താലിൻ എന്ന കളനാശിനിയുടെ പ്രയോഗത്തിനു പുറമേ മുപ്പതാം ദിവസം നൽകുന്ന കൈകൊണ്ടുള്ള കളപറിക്കൽ; ഇരുപതാം ദിവസവും നാല്പത്തിയഞ്ചാം ദിവസവും ഓരോന്ന് വീതം നൽകുന്ന കൈകൊണ്ടുള്ള കളപറിക്കൽ. ഇതിനു പുറമേ കള നിയന്ത്രണം ചെയ്യാത്ത ഒരു ട്രീട്മെന്റും ഉൾപെടുത്തിയിട്ടുണ്ട്.

ഈ പരീക്ഷണത്തിൽ നിന്നും ഓണാട്ടുകരയിലെ വേനൽക്കാല നിലക്കടല കൃഷിക്ക് ഇമസെത്താപൈർ എന്ന കളനാശിനി ഹെക്ടറിനു 70 ഗ്രാം എന്ന അളവിൽ ഇരുപതാം ദിവസം പ്രയോഗിക്കുന്നതാണ് കള നിയന്ത്രണത്തിന് ഏറ്റവും ഫലപ്രദവും, വിളവു വർദ്ധിപ്പിക്കുന്നതും, ലാഭകരവുമായ രീതി എന്ന് കണ്ടെത്തി.