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Research Article

Impact of multi mix herbicide on growth and weed indices in irrigated groundnut (*Arachis hypogaea* L.)

Nivetha C*
Department of Agronomy, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai-625104 (Tamil Nadu), India
Paulpandi V K
Department of Agronomy, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai-625104 (Tamil Nadu), India
Durai Singh R
Department of Agronomy, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai-625104 (Tamil Nadu), India
Kumutha K
Department of Agricultural Microbiology, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai-625104 (Tamil Nadu), India
Kannan P
Department of Soil Science and Agriculture Chemistry, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai-625104 (Tamil Nadu), India

*Corresponding author. Email: cnivetha000@gmail.com

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Abstract
Food and nutritional security for the country India depends on the agriculture sector. Groundnut is an important food legume cum oilseed crop and weed infestation is the major problem causing yield reduction. Therefore, the field experiment study was conducted during the *winter* season of 2022 at Central farm**,** Agriculture College and Research Institute in Madurai to evaluate the newer multi-mix herbicide combinations and find out the appropriate weed management practices for yield enhancement and weed suppression in irrigated groundnut (*Arachis hypogaea* L.). The experiment consisted of twelve treatments (T_1 to T_{12}) laid out in a randomized complete block design. Among the weed flora, almost two third of the weed infestation was documented as broad-leaved weeds (51%), followed by grassy weeds (36%) and less infestation by sedges (13%) in groundnut at the experimental site. Application of pre-emergence alone and post-emergence alone does not suppress the weed infestation efficiently. For that, this study focused on using multi-mixed herbicides along with hand weeding to determine herbicide's efficacy on weed control and growth parameters. Among the weed control methods, weed-free check (T_{12}) increased the growth parameters *viz*., Plant height (65.3 cm), Leaf Area Index (4.34) and Dry matter accumulation (5536 kg ha^{-1}) and higher weed control efficiency (99.2%). Among the herbicidal treatments, pre emergence application of pendimethalin + imazethapyr (ready mix) followed by hand weeding at 40 days after sowing (T_7) gave significantly (P=0.05) higher results in growth components of groundnut and weed suppression compared to other herbicidal treatments.

Keywords: Groundnut, Herbicide combinations, Pre-emergence, Post-emergence, Weed control efficiency

INTRODUCTION

Groundnut, also known as monkey nut or poor man's cashew nut or earth nut (Arachis hypogaea L.), belongs to the genus Arachis of the family Leguminosae, is said to be the "King of oilseed" in the world. It is one of the most important foods, legume crops with higher protein (22-30%) and oil content (44-56%). By 2050, the current global population (2021) of 7.7 billion is expected to reach over 9 billion to meet the demand for food, and world food production needs to be increased by 70 to 100% (Food and Agriculture Organization of the United Nations, 2021).

Groundnut (*Arachis hypogaea* L.) is India's fourth most important food legume and oilseed crop, cultivated over an area of 6.65 lakh ha with a production of 1.56 m t and average productivity of 2352 kg ha^{-1} (www.indiastat.com, 2019-20). Due to various reasons,

under the irrigated condition, groundnut productivity is not stable. Among them, one of the major reasons is weed infestation. Groundnut, slow growth at initial time, it provides a congenial atmosphere for profuse weed growth. Removal of weeds throughout the cropping period might not be economical. Exact crop weed competition at a critical period for groundnut has to be evaluated to reduce extravagant weed control expenses (Korav *et al*., 2020). A yield loss of 35 to 80 per cent in groundnut due to invasive weed competition. Weeds compete with the crop for nutrients, space and other resources and also impede pod development, pegging and harvesting of the crop (Kumari *et al*., 2021). Presently, a wide variety of old and new-generation herbicides are available and recommended for controlling weeds. Using pre-and post-emergence herbicides offers a viable alternative option for effective and timely control of weeds in groundnut cultivation. But, each herbicide has its own spectrum of weed control. The herbicide application timing also concerns weed control efficiency (Mishra, 2020). Thus, the present study aimed to evolve an efficient and economically viable system for managing weeds in irrigated groundnut (*Arachis hypogaea* L.).

MATERIALS AND METHODS

A field trial was conducted at Field No 32, Central Farm, Department of Agronomy Agricultural College and Research Institute, Madurai, Tamil Nadu during winter 2022. The experimental site is geographically positioned at 9º 54' N latitude and 78º 80' E longitude with an altitude of 147 m above mean sea level coming under the southern agro-climatic zone of Tamil Nadu. Soil was sandy clay loam and taxonomically known as *Typic udic hapustalf,* with a bulk density of 1.28 mg cc^{-1}. Initial soil samples were collected from the experimental field before sowing and analysed for available nitrogen (N) (Subbiah and Asija, 1956), phosphorous (P_2O_5) (Olsen, 1954) and potassium (K_2O) (Stanford and English, 1949).The nutrient status was found to be low (208 kg ha^{-1}), medium (17 kg ha^{-1}) and medium (196 kg ha^{-1}) with respect to available nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O). Total rainfall during the cropping season was 152.6 m, with good distribution. Twelve treatments consisted of various combinations *viz*., PE Pendimethalin @ 3.3 l ha^{-1} followed by Hand weeding on 40 DAS (T_1), PE Pendimethalin @ 3.3 l ha^{-1} followed by POE Quizalofop ethyl 7.5% + Imazethapyr 15% EC (ready mix) @ 437.5 ml ha^{-1} (T_2), PE Pendimethalin @ 3.3 l ha^{-1} followed by POE Imazethapyr @ 750 ml ha^{-1} (T_3), PE Oxyflourfen @ 250 g ha^{-1} followed by Hand weeding on 40 DAS (T_4), PE Oxyflourfen @ 250 g ha^{-1} followed by POE Quizalofop ethyl 7.5% + Imazethapyr 15% EC (ready mix) @ 437.5 ml ha^{-1} (T_5), PE Oxyflourfen @ 250 g ha^{-1} followed by POE Imazethapyr @ 750 ml ha^{-1} (T_6), PE Pendimethalin 30% + Imazethapyr 2% EC (ready mix) @ 1.0 kg a.i ha^{-1} followed by Hand weeding on 40 DAS (T_7), PE Pendimethalin 30% + Imazethapyr 2% EC (ready mix) @ 1.0 kg a.i ha^{-1} followed by POE Quizalofop ethyl 7.5% + Imazethapyr 15% EC (ready mix) @ 437.5 ml ha^{-1} (T_8), PE Pendimethalin 30% + Imazethapyr 2% EC (ready mix) @ 1.0 kg a.i ha^{-1} followed by POE Imazethapyr @ 750 ml ha^{-1} (T_9), Hand weeding at 20 and 40 DAS (T_{10}), Unweeded check (T_{11}) and Weed free check (T_{12}) was laid out in randomized block design and replicated thrice. Groundnut variety TMV 14 was sown on 11th January 2022 at a spacing of 30X10 cm using a seed rate of 125 kg ha^{-1}. Herbicides were applied using a knapsack sprayer fitted with a flat fan nozzle calibrated to deliver 500 litres of water per hectare. All other cultural practices were done by the recommended package of practices for groundnut.

The density and dry weight of weeds were observed with the help of a quadrate (0.25 m^2) placed randomly at four places during the crop harvest. Identified the weeds present in the experimental site in each plot and the data on weed density and dry weight were subjected to square root transformation before statistical analysis by Analysis of variance (ANOVA) method as recommended by Gomez and Gomez (1984). Whenever the differences between the treatments were found to be significant, critical differences (CD) were worked out at a five per cent probability level and the resulting values were provided. Biometric observations were taken from 5 random plants in each plot.

RESULTS AND DISCUSSION

Impact of herbicides on growth parameters

Plant height

The data presented in Table 1 obtained during the cropping period on plant height was significantly (P=0.05) influenced by all the weed management practices. While among all treatments, weed-free check (T_{12}) resulted in significantly higher plant height (65.3 cm). This might be due to the minimum or no crop weed competition for resources like light, moisture, nutrients and air in the critical period, leading to higher values in growth parameters. This was followed by Pre-emergence application of Pendimethalin 30% + Imazethapyr 2% EC (ready mix) @ 1.0 kg a.i ha^{-1} followed by hand weeding on 40 DAS (T_7), which recorded plant hight of 59.6 cm and it was statistically on par with manual hand weeding at 20 and 40 DAS (T_{10}) were registered taller plants (58.8 cm). As suggested by Wesley *et al*. (2008), the use of herbicides and hand weeding significantly improved the growth components

when compared to unweeded control, because it experienced lesser weed growth and density that allowed more space, light and nutrients for groundnut root growth, nodulation and best extension of leaves and branches. Lower plant height (33.6 cm) was observed in unweeded check (T_{11}) (Fig.1), which might be due to severe competition exerted by monocots and dicot weeds throughout the cropping period of groundnut by shading effect of weeds or overcrowding in the crop-weed ecosystem. These findings were also reported by Kadavkar (1999), Sonwalkar (2005), Jadhav (2007), Kumawat (2014) and Shah and Pramanik (2020) because of heavier competition among the broad spectrum of weeds in the unweeded check plant height and other growth parameters have been reduced in groundnut.

Leaf area index (LAI)

Among the different weed management practices, weed-free check (T_{12}) registered maximum LAI (4.43) and was statistically on par with manual weeding at 20 and 40 DAS (T_{10}) (4.20). This was closely followed by Pre-emergence application of Pendimethalin 30% + Imazethapyr 2% EC (ready mix) @ 1.0 kg a.i ha^{-1} along with one hand weeding on 40 DAS (T_7). The minimum LAI (1.97) was observed with an Unweeded check (T_{11}). Because, the timely and effective control of weeds are expected to have greater availability of nutrients, moisture and solar radiation to crop plants, increasing total chlorophyll content, photosynthetic rate and nitrate reductase activity which leads to higher supply of carbohydrates and increased growth attributes than unweeded check. These results corroborate with Channappagouder *et al*. (2008) for radish and Suseendran *et al*. (2019) for groundnut.

Dry matter accumulation (DMP)

All the weed control treatments tried significantly (P=0.05) influenced on dry matter production. Weed-free check (T_{12}) registered higher DMP (5536 kg ha^{-1}) and this was statistically on par with two hand weeding at 20 and 40 DAS (T_{10}) (5468 kg ha^{-1}). This treatment was closely followed by Pre emergence application of Pendimethalin 30% + Imazethapyr 2% EC (ready mix) @ 1.0 kg a.i ha^{-1} along with one hand weeding on 40 DAS (T_7) (5090 kg ha^{-1}) and PE Pendimethalin 30% + Imazethapyr 2% EC (ready mix) @ 1.0 kg a.i ha^{-1} followed by POE Quizalofop ethyl 7.5% + Imazethapyr 15% EC (ready mix) @ 437.5 ml ha^{-1} (T_8). Unweeded check (T_{11}) revealed the least DMP (2882 kg ha^{-1}). Suseendran *et al*. (2019) also reported that unweeded control recorded the least DMP in ground-

Table 1. Impact of weed treatments on growth parameters at harvest (95 DAS)

	Treatments	Plant height (cm)	LAI	DMP (kg ha^{-1})
T_1	PE PDN @ 3.3 l ha^{-1} *fb* HW on 40 DAS	53.6	3.47	4646
T_2	PE PDN @ 3.3 l ha^{-1} *fb* POE QUIZ 7.5% + IMAZ 15% EC (ready mix) @ 437.5 ml ha^{-1}	47.0	3.03	4185
T_3	PE PDN @ 3.3 l ha^{-1} *fb* POE IMAZ @ 750 ml ha^{-1}	43.1	2.63	3727
T_4	PE Oxyflourfen @ 250 g ha^{-1} *fb* HW on 40 DAS	43.3	2.70	3955
T_5	PE Oxyflourfen @ 250 g ha^{-1} *fb* POE QUIZ 7.5% + IMAZ 15% EC (ready mix) @ 437.5 ml ha^{-1}	38.8	2.37	3330
T_6	PE Oxyflourfen @ 250 g ha^{-1} *fb* POE IMAZ @ 750 ml ha^{-1}	42.8	2.47	3470
T_7	PE PDN 30% + IMAZ 2% EC (ready mix) @ 1.0 kg a.i ha^{-1} *fb* HW on 40 DAS	59.6	4.03	5090
T_8	PE PDN 30% + IMAZ 2% EC (ready mix) @ 1.0 kg a.i ha^{-1} *fb* POE QUIZ 7.5% + IMAZ 15% EC (ready mix) @ 437.5 ml ha^{-1}	53.3	3.67	5041
T_9	PE PDN 30% + IMAZ 2% EC (ready mix) @ 1.0 kg a.i ha^{-1} *fb* POE IMAZ @ 750 ml ha^{-1}	49.6	3.20	4482
T_{10}	HW at 20 and 40 DAS	58.8	4.20	5468
T_{11}	Unweeded check	33.6	1.97	2882
T_{12}	Weed free check	65.3	4.43	5536
SEd		2.42	0.18	214
CD (P = 0.05)		5.02	0.38	446

fb – followed by, PE- Pre emergence, POE-Post Emergence, HW-Hand weeding, PDN- Pendimethalin, IMAZ- Imazethapyr, QUIZ – Quizalofop ethyl

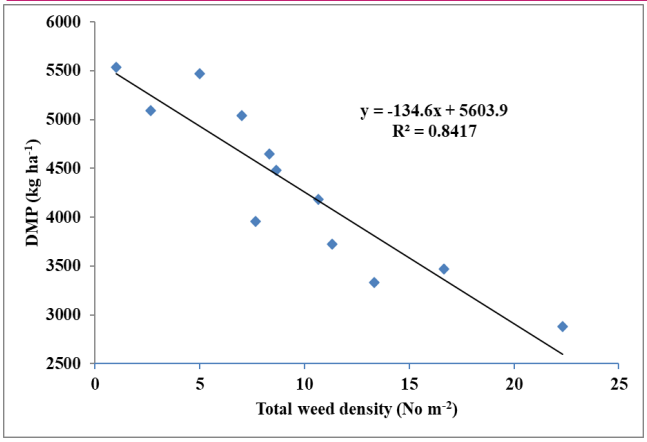

Fig. 1. *Relationship between total weed density and DMP of groundnut*

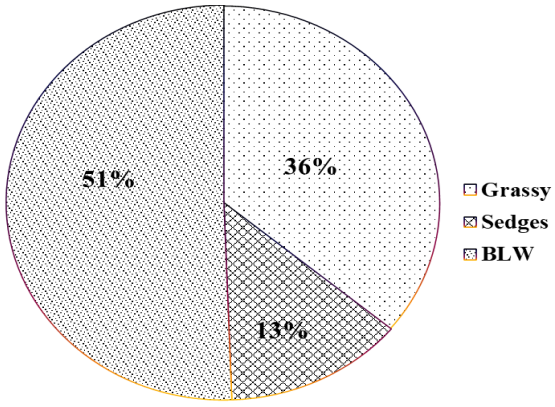

Fig. 2. *Dominance of weed density at the experimental site in groundnut*

nut. Dry matter accumulation of groundnut linearly decreased as the density of weeds increased and the weeds infestation accounted for nearly 84.17 % variation in dry matter accumulation (Fig. 1).

Impact of herbicides on weed parameters

Weed flora

Among the weed flora, almost two third of the weed infestation was caused by broad leaved weeds (51%) followed by grassy weeds (36%) and less infestation by the sedges (13%) in groundnut at the experimental site (Fig. 2). Major dominating weeds were bermuda grass (*Cynodon dactylon*), hairy crab grass (*Digitaria sangunalis*) and barnyard grass (*Echinochloa colana*) in grassy weeds and black pigweed (*Trianthema portulacastrum*), false daisy (*Eclipta prostrata*) and tick weed (*Cleome viscosa*) in broadleaved weeds and less infestation only with purple nutsedge (*Cyprus rotundus*) in sedges.

Weed density

All the weed control treatments significantly (P=0.05) reduced the weed density and dry weight of weeds over the unweeded check. Among the weed control methods weed free check (T_{12}) resulted in lower density (1 no m^{-2}) (Table 2). It was followed by pre emergence application of Pendimethalin 30% + Imazethapyr 2% EC (ready mix) @ 1.0 kg a.i ha^{-1} followed by hand weeding on 40 DAS (T_7), resulted in reduced weed density (2.67 no m^{-2}). Next to this PE Pendimethalin 30% + Imazethapyr 2% EC (ready mix) @ 1.0 kg a.i ha^{-1} followed by POE Quizalofop ethyl 7.5% + Imazethapyr 15% EC (ready mix) @ 437.5 ml ha^{-1} (T_8) and manual hand weeding at 20 and 40 DAS (T_{10}) reduced the weed density. Higher weed density (22.33 no m^{-2}) was reported in the unweeded check (T_{11}). According to Kirde *et al*. (2019) there was no weed competition at the early stages of the crop for nutrients, light and space might be the reason for lower weed density and weed dry weight in groundnut. Application of any POE herbicides without hand weeding or pre-emergence herbicides resulted in poor weed control in *rabi* groundnut (Sagvekar *et al.,* 2015). This led to repetitive flushes of fresh weed at different stages of groundnut and more competition (Mohanty *et al*., 2019).

Weed dry weight

Weed free check (T_{12}) significantly (P=0.05) reduced the dry weight of weeds (0.16 g m^{-2}) and this was on par with pre emergence application of Pendimethalin 30% + Imazethapyr 2% EC (ready mix) @ 1.0 kg a.i ha^{-1} followed by hand weeding on 40 DAS (T_7) in dry weight of weeds (0.57 g m^{-2}) and hand weeding twice at 20 and 40 DAS (T_{10}). Higher weed dry weight (21.19 g m^{-2}) resulted in unweeded check (T_{11}). This could be the result of unrestricted growth in this system, where the weeds continued to grow freely and efficiently and benefited from all the growth factors, leading to higher dry matter accumulation of weeds (Kumari *et al*., 2021).

Weed control efficiency

Regarding weed control efficiency, all the weed control methods significantly (P=0.05) increased the efficiency. Among them, weed-free check (T_{12}) recorded higher weed control efficiency (99.2%). Effective control of weeds at critical weed competition at the early stages might be the reason for reduced weed observations and increased weed control efficiency in weed-free checks. Pre-emergence application of Pendimethalin 30% + Imazethapyr 2% EC (ready mix) @ 1.0 kg a.i ha^{-1} followed by hand weeding on 40 DAS (T_7) was found to register significantly higher weed control efficiency (97.3) (Fig. 3) after the weed-free check. The reason behind this was due to application of pendimethalin which hampered emergence of monocot weeds especially grassy weeds by arresting root and shoot growth of weeds, while imazethapyr classified as imidazolione herbicides and their mode of action is to inhibit the aceto hydroxyl acid synthase (AHAS) or acetolactate synthase (ALS) in broadleaved weeds which caused disin-

Table 2. Impact of weed treatments on weed dynamics, weed biomass on groundnut

	Treatments	Weed dynamics at harvest (No m^{-2}) (95 DAS)				Weed biomass (g m^{-2})
		Grassy	Sedges	BLWs	Total	
T_1	PE PDN @ 3.3 l ha^{-1} *fb* HW on 40 DAS	1.56 (2.00)	0.71 (0.00)	2.61 (6.33)	2.96 (8.33)	2.15 (4.13)
T_2	PE PDN @ 3.3 l ha^{-1} *fb* POE QUIZ 7.5% + IMAZ 15% EC (ready mix) @ 437.5 ml ha^{-1}	1.76 (2.67)	1.17 (1.00)	2.73 (7.00)	3.32 (10.67)	2.33 (4.96)
T_3	PE PDN @ 3.3 l ha^{-1} *fb* POE IMAZ @ 750 ml ha^{-1}	1.93 (3.33)	1.66 (2.33)	2.48 (5.67)	3.44 (11.33)	2.44 (5.46)
T_4	PE Oxyflourfen @ 250 g ha^{-1} *fb* HW on 40 DAS	1.68 (2.33)	0.71 (0.00)	2.39 (5.33)	2.83 (7.67)	2.00 (3.54)
T_5	PE Oxyflourfen @ 250 g ha^{-1} *fb* POE QUIZ 7.5% + IMAZ 15% EC (ready mix) @ 437.5 ml ha^{-1}	2.40 (5.33)	1.86 (3.00)	2.34 (5.00)	3.70 (13.33)	2.81 (7.41)
T_6	PE Oxyflourfen @ 250 g ha^{-1} *fb* POE IMAZ @ 750 ml ha^{-1}	2.54 (6.00)	1.76 (2.67)	2.91 (8.00)	4.14 (16.67)	2.84 (7.59)
T_7	PE PDN 30% + IMAZ 2% EC (ready mix) @ 1.0 kg a.i ha^{-1} *fb* HW on 40 DAS	1.34 (1.33)	0.71 (0.00)	1.34 (1.33)	1.76 (2.67)	1.03 (0.57)
T_8	PE PDN 30% + IMAZ 2% EC (ready mix) @ 1.0 kg a.i ha^{-1} *fb* POE QUIZ 7.5% + IMAZ 15% EC (ready mix) @ 437.5 ml ha^{-1}	2.02 (3.67)	0.88 (0.33)	1.86 (3.00)	2.73 (7.00)	1.81 (2.78)
T_9	PE PDN 30% + IMAZ 2% EC (ready mix) @ 1.0 kg a.i ha^{-1} *fb* POE IMAZ @ 750 ml ha^{-1}	2.00 (3.67)	1.22 (1.00)	2.11 (4.00)	3.01 (8.67)	1.75 (2.57)
T_{10}	HW at 20 and 40 DAS	1.93 (3.33)	0.71 (0.00)	1.46 (1.67)	2.33 (5.00)	1.32 (1.30)
T_{11}	Unweeded check	2.78 (7.33)	2.30 (5.00)	3.24 (10.00)	4.78 (22.33)	4.64 (21.19)
T_{12}	Weed free check	0.88 (0.33)	0.71 (0.00)	1.05 (0.67)	1.22 (1.00)	0.81 (0.16)
SEd		0.26	0.19	0.15	0.23	0.17
CD (P = 0.05)		0.54	0.40	0.32	0.48	0.36

The values in parenthesis are subjected to square root ($\sqrt{x + 0.5}$) transformation; *fb* – followed by, PE- Pre emergence, POE-Post Emergence, HW-Hand weeding, PDN- Pendimethalin, IMAZ- Imazethapyr, QUIZ – Quizalofop ethyl

tegrating the weeds at 3-4 leaf stage. Late emerging weeds were removed by manual hand weeding at 40 days after sowing. According to Rao *et al*. (2011), the lowest weed density, weed dry matter and the greatest weed control efficiency were recorded in hand weeding twice, pendimethalin followed by hand weeding and imazethapyr followed by hand weeding at 40 DAS. Kalhapure *et al*. (2013) reported that pendimethalin 1.5 kg / ha as PE + imazethapyr 0.015 kg/ha as POE + Hand weeding at 40 DAS had better results in all weed management practices and growth attributes. Results from Jadhav *et al*. (2015) reported that the treatment pendimethalin @ 1 kg ha^{-1} at 2 DAS + 1 hoeing at 45DAS was proved to be significantly superior to other treatments and control in respect of weed index, weed control efficiency as well as lowest weed population (No./0.25 m^2) and weed dry weight (g/0.25 m^2). In the present study, newer herbicide combination molecules such as multi-mix with lower doses and formulations, showed high efficacy in controlling the broad spectrum of weed species.

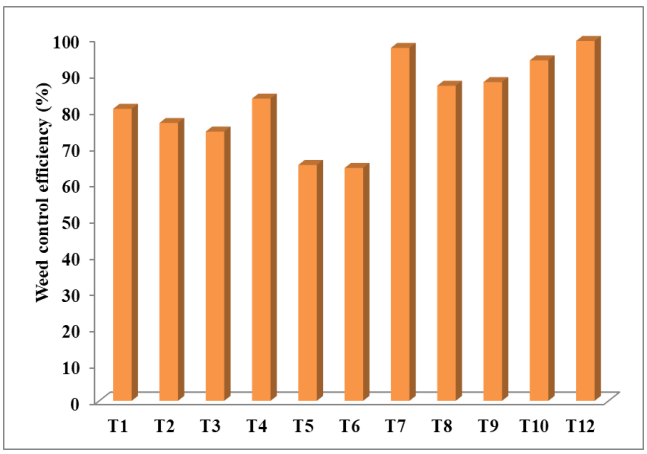

Fig. 3. *Weed control efficiency (%) of groundnut at harvest stage (95 DAS)*

Conclusion

Based on the experimental findings, it could be suggested that weed-free check (T_{12}) and hand weeding twice at 20 and 40 DAS (T_{10}) had given better groundnut growth parameters and significantly (P=0.05)

reduced weed populations and increased weed control efficiency. Because of the labour constraints and labour costs, a better alternative option was the chemical method of weed control, which was cheaper, easily available, and economical. It was noticed that the integration of one-hand weeding with the use of herbicides had given the best results. Among the herbicidal treatments, pre-emergence application of Pendimethalin 30% + Imazethapyr 2% EC (ready mix) @ 1.0 kg a.i ha^{-1} followed by one hand weeding on 40 DAS (T_7) and PE Pendimethalin 30% + Imazethapyr 2% EC (ready mix) @ 1.0 kg a.i ha^{-1} followed by POE Quizalofop ethyl 7.5% + Imazethapyr 15% EC (ready mix) @ 437.5 ml ha^{-1} (T_8) was the effective and economical method for managing the broad spectrum of weeds in groundnut under labour scarcity.

Conflict of interest

The authors declare that they have no conflict of interest.

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