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Bio-efficacy of herbicides weed management in groundnut under lateritic soil of West Bengal

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ABSTRACT

A field experiment was carried out during rabi season at Agricultural Farm, Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan, Birbhum to study 'Effect of fomesafen + fluazifop-p-butyl on growth and productivity of ground nut in lateritic soil of West Bengal' during 2017-18. The experimental soilcontains high percentage of sand (62.0%) and low percentage of clay (25.5%). The soil was somewhat acidic, low in soil organic carbon, available nitrogen and phosphorus whereas potassium content in soil is medium. The experiment was laid out in randomized block design with ten treatments i.e. T_1-Fomesafen + fluazifop-p-butyl @ 100+100g ha^{-1}, T_2-Fomesafen + fluazifop-p-butyl @ 125+125 g ha^{-1}, T_3-Fomesafen + fluazifop-p-butyl @ 150+150 g ha^{-1}, T_4-Fomesafen + fluazifop-p-butyl @ 175+175 g ha^{-1}, T_5-Fomesafen + fluazifop-p-butyl @ 250+250 g ha^{-1}, T_6-Imazethapyr @100.0 g ha^{-1}, T_7- Fluazifop-p-butyl + fomesafen@ 125+125 g ha^{-1} (Fusiflex), T_8-Hand Weeding at 15 and 30 Days after Sowing (DAS), T_9-Weedy check and T_{10}-Weed free check and replicated thrice. Result showed that weed management had positive and favourable influence in improving plant height, yield attributes like number of pods plant^{-1}, number of kernel pod^{-1} and 100 kernel weight of groundnut under study. The doses of fomesafen + fluazifop-p-butyl at (125+125,150+150, 154.4 and 250+250 g ha^{-1}) significantly reduced the weed infestation and registered lower weed density, weed dry weight, weed index, higher weed control efficiency and yield attributes and yield of groundnut over T_6-Imazethapyr @ 100.0 g ha^{-1}, T_7- Fluazifop-p-butyl + fomesafen @ 125+125 g ha^{-1} (Fusiflex) and at par with two hand weeding. Although fomesafen + fluazifop-p-butyl at 175+175 g ha^{-1} registered the higher gross return, net return and B:C ratio but it was at par with fomesafen + fluazifop-p-butyl @125+125 g ha^{-1}, fomesafen + fluazifop-p-butyl at150+150 g ha^{-1} and fomesafen + fluazifop-p-butyl @250+250 g ha^{-1}. Fomesafen+ fluazifop-p-butyl @125+125 g ha^{-1} appeared as effective and economic for managing broad spectrum weedsof rabi ground nut in lateritic soil of West Bengal.

Keywords: Fomesafen + fluazifop-p-butyl, groundnut, weed control efficiency, weed index

Groundnut (*Arachis haypogaea* L.) is also known as poor man's cashew nut and wonder nut and belongs to the family Fabaceae (Gregory *et al*., 1973). It is the 13th most important food crop and 4th most important oil seed crop of the world. It is grown in nearly 100 countries. Groundnut (*Arachishypogaea* L.) is the most important oilseed crop of tropical and subtropical regions of the world. It is an annual unpredictable legume cum oilseed crop. Groundnut oil is composed of mixed glycerides and contains a high proportion of unsaturated fatty acids, in particular, oleic (50-65%) and linoleic (18-30%) (El Naim *et al*., 2010).

In India groundnut is grown over an area of 4898.7 thousand hectare out of which 4076 thousand hectare during *kharif* season and 822.7 thousand hectare during *rabi* season (Anonymous, 2018). Production of groundnut in India during 2018 was 4898.7 thousand tonne out of which 7365.3 thousand tonne during *kharif* season and 1577.2 thousand tonne during *rabi* season (Anonymous, 2018). Productivity of groundnut in India during 2018 was 1825 kg ha^{-1}, during *kharif* season it was 1807 kg ha^{-1} and 1917 kg ha^{-1} during *rabi* season (Anonymous, 2018). The groundnut area in West Bengal was 932 thousand hectare, production 1053.3 thousand tonnes and productivity was 1130 kg ha^{-1} which was below national average (Anonymous, 2018). The per capita availability of oilseeds is 13 g day^{-1} person^{-1}, which is much below the recommendation of Indian Council of Medical Research (35-40 g day^{-1} person^{-1}). So increasing groundnut production is the foremost concern by overcoming all production losses.

The yield of groundnut is lost in various ways, among all, weed infestation is considered as one of the major factor and the first 30-40 days of crop-weed competition in *rabi* groundnut is critical due to the initial slow growth habit of the crop and low temperature during the month of January. Weed interference resulted in maximum yield losses between 74 and 92 per cent (Agostinho *et al.*, 2006). The critical period of crop weed competition for groundnut crop was reported to be up to 45 DAS (Rao, 2000). Hence for achieving maximum yield, timely and effective weed management during the critical period of weed competition become essential. Manual weeding is very laborious, time consuming and expensive, utmost importantly when there is dearth of manpower (Ikisan, 2000). So late weeding operation is usual and it causes decrease in crop yields and also increases the incidence of pests and diseases which are difficult to control.

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Therefore, it is very important to find out proper herbicides that can manage the weeds economically and safely. From the conventional method of hand weeding and hoeing along with modernized methods of weed management through application of herbicides for effective weed control, and to meet the labour shortage during the peak period of agricultural demand, increased cost of weeding operation (Annadurai *et al.*, 2010).

Weed management in ground nut has been found to be easier; less labour and less time consuming and less costly and most effective in reducing weed threat compared to hand weeding through herbicides (Kumar, 2009). Application of post-emergence herbicides like imazethapyr (Grichar, 2001) or glyphosate (Chaudhari *et al.*, 2007) or flauzifop-butyl (Gowda *et al.*, 2002) or quizalofop-p-ethyl (Bhatt, 2008) or chlorimuron-ethyl (Dubey *et al*., 2010) was recommended for managing of weeds effectively at later stages of growth of groundnut crop. The pre-emergence application of herbicides such as pendimethalin (Chaudhari *et al*., 2007) or oxyfluorfen or metalachlor (Dutta *et al*., 2005) or alachlor (Roychoudhury *et al*., 2011) are used formanaging weeds during early stages but this allows the emergence of weeds at later stages. Hence the agronomic experiment was conducted to find out practically convenient and economically feasible and environmentally safely methods of weed management practices in groundnut. Henceforth the objective of this study was to find the effect of weed management practices on the growth and productivity of groundnut.

MATERIALS AND METHODS

Experiment was conducted in a field at the Institute of Agriculture Farm, Visva-Bharati, Sriniketan of Birbhum district in West Bengal, India. It lies ($20^0 39^/$N latitude and $87^0 42^/$E longitude with an average altitude of 58.9 m amsl under typical semi-arid tropical climate during rabiseason of 2017-18 on well drained sandy loam soil.Maximum and minimum temperature varied from 35.9^{0}C and 8.81^{0}C during winter 2017-18. Relative humidity prevailed between 89.07 and 40.27 per cent and maximum and minimum sunshine hours during the experimental period was 8.22 and 5.44 hours. Total rainfall received during the crop growth period (November to May) 139.46 mm during winter 2017-18. The initial fertility status of the soil was 141.0 kg ha^{-1} alkaline permanganate oxidizable nitrogen (N) (Subbiah and Asija, 1956), 11.9 kg ha^{-1} available phosphorus (P) (Bray and Kurtz, 1945), 160.5 kg ha^{-1} 1 N ammonium acetate exchangeable potassium (K) (Hanway and Heidel, 1952) and 0.48% organic carbon (Walkley and Black, 1934). The pH of the soil was 6.10 (1:2.5 soil: water ratio) (Prasad *et al*., 2006). The experiment was laid out in randomized block design with three replications. Groundnut variety “TG-24” was sown at spacing of 30 x10 cm. A basal dose of 25 kg N, 50 kg P_2O_5 and 60 kg K_2O ha^{-1} was applied through urea, single super phosphate and muriate of potash, respectively. Herbicides were applied through using manually operated knapsack sprayer fitted with flat fan nozzle using spray volume of 500L ha^{-1}. The details of the treatments T_1: Fomesafen11.1% w/w (12.5% w/v) + Fluazifop-p-butyl 11.1% w/w (12.5% w/v) SL @ 100 +100 g ha^{-1}, T_2: Fomesafen 11.1% w/w (12.5% w/v) + Fluazifop-p-butyl 11.1% w/w (12.5% w/v) SL @ 125+125 g ha^{-1}, T_3: Fomesafen 11.1% w/w (12.5% w/v) + Fluazifop-p-butyl 11.1% w/w (12.5% w/v)SL@ 150+150 g ha^{-1}, T_4: Fomesafen 11.1% w/w (12.5% w/v) + Fluazifop-p-butyl 11.1% w/w (12.5% w/v) SL@ 175+175 g ha^{-1}, T_5: Fomesafen 11.1% w/w (12.5% w/v) + Fluazifop-p-butyl 11.1% w/w (12.5% w/v) SL@ 250+250 g ha^{-1}, T_6: Imazethapyr @ 100.0 g ha^{-1}, T_7: Fluazifop-p-butyl11.1% w/w (12.5% w/v)+ fomesafen11.1% w/w (12.5% w/v)@ 125+125 g ha^{-1} (Fusiflex), T_8: Hand Weeding at 15 & 30 Days after Sowing (DAS), T_9: Weedy check and T_{10}:Weed free check. The fomesafen + fluazifop-p-butyl and imazethapyr herbicides were applied on 15 days after sowing as these were the post emergence herbicide. Weed free check was achieved by weekly interval of hand weeding was done throughout the crop period. Regarding five plants were selected from each plot and regular biometric observations of crop and weed parameters were recorded from 15 days after sowing (DAS) upto 60 DAS. However, observation data recorded at 30, 45 and 60 DAS are given in tables for study the results and discussion. Weed density (no. m^{-2}) was recorded by putting a quadrate of 0.25m^2 at two random spots in each plot. The weed control efficiency was worked out based upon the data from weed dry weight in the field and the formula used was suggested by Mani *et al.* (1973).

$$\text{WCE (\%)} = \frac{\textit{Weed dry weight in the untreated plot - Weed dry weight in the treated plot}}{\textit{Weed dry weight in the untreated plot}} \times 100$$

$$\text{WI (\%)} = \frac{\textit{Yield from the weed free plot} - \textit{Yield from the treated plot}}{\textit{Yield from the weed free plot}} \times 100$$

The final weed data (weed count and weed dry weight) was transformed using the formula $(X+0.5)^{0.5}$ for analysis purpose. Weed index indicates the reduction in crop yield due to crop weed competition as compared to weed free plot. Weed index (WI) was worked out by using the formula given by Gill and Kumar (1969).

Plant Height and plant dry matter at 30, 45 and 60 DAS were recorded for randomly selected five plants. Data on Pod yield (kg ha^{-1}) and yield components *viz.*, number of pods $plant^{-1}$, number of kernel pod^{-1} and 100 kernel weight. Gross returns were calculated based on local market prices of groundnut and net returns by subtracting the total cost of cultivation from gross returns. Benefit : cost ratio was computed by dividing gross returns with cost of cultivation.

RESULTS AND DISCUSSION

Effect on weeds

The experimental field was infested with three categories of weeds under nine families. The total no of species was 11 out of which *Echinochloa colona, Digitaria sanguinalis, Eleusine indica* and *Dactyloctenium aegyptium* among monocots; *Trianthem aportulacastrum, Gnaphalium polycephalum, Phyllanthus niruri, Spilanthe scalva, Digera arvensis* and *Chenopodium album* among broad leaved; *Cyperus rotundus* were present as a major weeds in groundnut field. *Gnaphalium polycephalum, Spilanthes calva* among broadleaved, *Digitaria sanguinalis* among the grasses and *Cyperus rotundus* among the sedges were predominant throughout the cropping period. Although a whole spectrum of weeds was present in the experimental field, these four weeds constituted maximum percentage of total weed flora.

All the herbicides revealed effective control of all categories of dominant weeds resulting in less weed density, weed dry matter and higher weed control efficiency as compared to weedy check. The number of dominant grassy, broadleaved and sedge weeds was gradually decreased with the increase of doses of tested herbicide fomesafen + fluazifop-p-butyl in 30, 45 and 60 DAS of observation. Better weed control was observed with application of Fomesafen + Fluazifop-p-butyl @250+250, 175+175, 150+150 and 125+125 g / ha of the tested herbicide. Lower weed biomass at 30 DAS was recorded with all fomesafen + fluazifop-p-butyl over other herbicides application. None of tested dose of fomesafen + fluazifop-p-butyl showed any phytotoxic effect on ground nut plant.

Total weed density

Weedy check (T_9) recorded significantly the highest grassy weed density over other weed management practices at 30, 45 and 60 DAS (Table 1). The lowest grassy weed density was registered under weed free plot (T_{10}). At 30, 45 and 60 DAS, among the herbicidal treatments lowest number of grassy weed was observed in plot treated with T_5-fomesafen + fluazifop-p-butyl@250+250 g ha^{-1} (0.00, 0.36 and 2.10) followed by T_4- fomesafen + fluazifop-p-butyl @175+175 g ha^{-1} (0.00, 0.38 and 2.43), T_3-fomesafen + fluazifop-p-buyl@150+150 g ha^{-1} (0.22, 0.44 and 2.60), T_2-fomesafen + fluazifop-p-butyl @125+125 g ha^{-1} (0.25, 0.47 and 2.61), T_6- Imazethapyr@ 100.0 g ha^{-1} (0.27, 0.88 and 2.98), T_7- fluazifop-p-butyl+ fomesafen @125+125 g ha^{-1} (0.58, 1.15 and 3.49) and T_1-fomesafen + fluazifop-p-butyl @100+100 g ha^{-1} (0.66, 1.89 and 3.99). The maximum weed density was recorded with T_9- weedy check (5.32, 13.71 and 18.75). There was no significant different among the treatments T_2, T_3, T_4 and T_5.

The statistical analysed data showed that weedy check (T_9) recorded significantly the highest broadleaved weed density over other weed management practices at 30, 45 and 60 DAS (Table 1). The lowest broadleaved weed density and weed dry weight was registered under weed free plot (T_{10}). At 30, 45 and 60 DAS, among the herbicidal treatments T_5-fomesafen + fluazifop-p-butyl@250+250 g ha^{-1} (0.00, 0.42 and 2.99) recorded lowest number of broadleaved weed followed by T_4-fomesafen + fluazifop-p-butyl@175+175 gha^{-1} (0.00, 0.44 and 3.27), T_3-fomesafen + fluazifop-p-buyl@ 150+150 g ha^{-1} (0.25, 0.55 and 3.57), T_2- fomesafen + fluazifop-p-butyl@125+125 g ha^{-1} (0.38, 0.60 and 3.65), T_7- fluazifop-p-butyl+fomesafen@ 125+125 g ha^{-1} (0.66, 1.46 and 4.81) and T_1- fomesafen + fluazifop-p-butyl @ 100+100 g ha^{-1} (1.04, 1.74 and 5.03) and T_6-Imazethapyr@ 100.0 g ha^{-1} (3.99, 13.56 and 26.62). The maximum weed density was recorded with T_9- weedy check (15.80, 34.64 and 59.52). There was no significant difference among the treatments T_2, T_3, T_4 and T_5.

The data showed that weedy check (T_9) recorded significantly higher sedge weed density over other weed management practices at 30, 45 and 60 DAS (Table 1). At 30, 45 and 60 DAS, among the herbicidal treatments T_5-fomesafen + fluazifop-p-butyl @ 250+250 g ha^{-1} (0.16, 0.36 and 1.22) recorded lowest number of sedge followed by T_4-fFomesafen + fluazifop-p-butyl @175+175 g ha^{-1} (0.17, 0.48 and 1.48), T_2- fomesafen + fluazifop-p-butyl @125+125 g ha^{-1} (0.24, 0.61 and 1.82) and T_3-fomesafen + fluazifop-p-buyl@150+150 g ha^{-1} (0.42, 0.63 and 1.67). Even all the fomesafen + fluazifop-p-buyl formulation except T_1- fomesafen + fluazifop-p-butyl @100+100 g ha^{-1} recorded lowest number of weed density than standard check *i.e.* T_7-fluazifop-p-butyl+fomesafen@125+125 g ha^{-1} and T_6-

Imazethapyr@ 100.0 g ha^{-1}. The maximum weed density was recorded with T_9- weedy check (5.32, 11.08 and 15.60). There was no significant difference among the treatments T_2, T_3, T_4 and T_5.

Total weed dry weight

The data showed that weedy check (T_9) recorded significantly higher grassy weed dry weight over other weed management practices at 30, 45 and 60 DAS (Table 2). At 30, 45 and 60 DAS, among the herbicidal treatments lowest dry weight of grassy weed was observed in plot treated with T_5-Fomesafen + Fluazifop-p-butyl @250+250 g ha^{-1} (0.00, 0.05 and 0.84 g m^{-2}) followed by T_4- Fomesafen + fluazifop-p-butyl @175+175 g ha^{-1} (0.00, 0.07 and 1.11 g m^{-2}), T_3-fomesafen + fluazifop-p-buyl@150+150 g ha^{-1} (0.01, 0.09 and 1.14 g m^{-2}), T_2- Fomesafen + fluazifop-p-butyl @125+125 g ha^{-1} (0.01, 0.10 and 1.02 g m^{-2}), T_6-Imazethapyr@ 100.0 g ha^{-1} (0.03, 0.21 and 1.37 g m^{-2}), T_7- fluazifop-p-butyl+fomesafen@125+125 g ha^{-1} (0.04, 0.25 and 1.87 g m^{-2}) and T_1- Fomesafen + fluazifop-p-butyl @100+100 g ha^{-1} (0.04, 0.32 and 1.46 g m^{-2}). The maximum weed density was recorded with T_9- weedy check (0.45, 2.85 and 7.98 g m^{-2}). There was no significant difference among the treatments T_2, T_3, T_4 and T_5.

Like grassy weed dry weight, among the herbicidal treatments T_5-Fomesafen + Fluazifop-p-butyl @ 250+250 g ha^{-1} recorded lowest dry weight of broadleaved (0.00 and 0.03 g m^{-2}) followed by T_4-Fomesafen + fluazifop-p-butyl @175+175 g ha^{-1} (0.00 and 0.04 g m^{-2}), T_3-fomesafen + fluazifop-p-buyl@150+150 g ha^{-1} (0.02 and 0.06 g m^{-2}), T_2-Fomesafen + fluazifop-p-butyl @125+125 g ha^{-1} (0.02 and 0.08 g m^{-2}), T_7- fluazifop-p-butyl+fomesafen@ 125+125 g ha^{-1} (0.04 and 0.14 g m^{-2}) and T_1- Fomesafen + fluazifop-p-butyl @ 100+100 g ha^{-1} (0.06 and 0.28 g m^{-2}) and T_6- Imazethapyr@100.0 g ha^{-1} (0.20 and 1.22 g m^{-2}) at 30 and 45. The maximum weed density was recorded with T_9- weedy check (0.95 and 3.21 g m^{-2}). At 60 DAS, among the herbicidal treatments T_5-Fomesafen + Fluazifop-p-butyl @250+250 g a.i. ha^{-1} recorded lowest dry weight of broadleaved (0.53 g m^{-2}) followed by T_4- Fomesafen + fluazifop-p-butyl @175+175 g ha^{-1} (0.62 g m^{-2}), T_2- Fomesafen + fluazifop-p-butyl @125+125 g ha^{-1} (0.64 g m^{-2}), T_3-fomesafen + fluazifop-p-buyl@ 150+150 g ha^{-1} (0.75 g m^{-2}), T_7- fluazifop-p-butyl+fomesafen@125+125 g ha^{-1} (0.95 g m^{-2}) and T_1-Fomesafen + fluazifop-p-butyl @100+100 g ha^{-1} (1.02 g m^{-2}) and T_6- Imazethapyr@ 100.0 g ha^{-1} (5.06 g m^{-2}). There was no significant differenceamong the treatments T_2, T_3, T_4 and T_5 at 60 DAS.

In case of sedge dry weight (Table 2), among the herbicidal treatments T_5-Fomesafen + Fluazifop-p-butyl @250+250 g ha^{-1} recorded lowest dry weight of sedge (0.02, 0.13 and 0.59 g m^{-2}) followed by T_4- Fomesafen + fluazifop-p-butyl @175+175 g ha^{-1} (0.02, 0.14 and 0.71 g m^{-2}), T_2- Fomesafen + fluazifop-p-butyl @125+125 g ha^{-1} (0.03, 0.17 and 0.80 g m^{-2}) and T_3-fomesafen + fluazifop-p-buyl@150+150 g ha^{-1} (0.05, 0.25 and 0.84 g m^{-2}). Even all the fomesafen + fluazifop-p-buylherbicide except T_1- Fomesafen + fluazifop-p-butyl @100+100 g ha^{-1} recorded lowest dry weight of sedge than standard check i.e. T_7- fluazifop-p-butyl+fomesafen@125+125 g ha^{-1} and T_6-Imazethapyr@ 100.0 g ha^{-1}. The maximum weed density was recorded with T_9- weedy check (0.67, 2.70 and 5.05 g m^{-2}). There was no significant differenceamong the treatments T_2, T_3, T_4 and T_5.

Effect on groundnut

Plant height

The data on plant height of groundnut were statistically analysed and presented in table 13. It showed that plant height of groundnut varied significantly during different growth stages with different treatments. The result showed that weed management practices recorded significantly taller plant over T_9- weedy check during its entire growth period.

At 30, 45 and 60 DAS, the highest plant height was recorded with T_{10}- weed free (9.6, 12.8 and 13.8 cm). The dwarf plant height was recorded with T_9- weedy check (7.2, 8.9 and 9.7 cm) which were significantly lower than other weed management treatments. Among herbicidal treatment, T_5- Fomesafen + Fluazifop-p-butyl @250+250 g ha^{-1} recorded maximum plant height (8.9, 12.7 and 13.7 cm) followed by T_4-fomesafen + fluazifop-p-buyl@175+175 g ha^{-1} (8.8, 12.2 and 13.6 cm), T_3-fomesafen + fluazifop-p-buyl@150+150 g ha^{-1} (8.8, 12.0 and 13.3 cm), T_2- Fomesafen + fluazifop-p-butyl @125+125 g ha^{-1} (8.6, 11.9 and 13.3 cm), T_7- fluazifop-p-butyl+fomesafen@125+125 g ha^{-1} (8.6, 11.8 and 13.0 cm), T_1- Fomesafen + fluazifop-p-butyl at 100+100 g ha^{-1} (8.0, 10.9 and 12.7 cm) and T_6- Imazethapyr@ 100.0 g ha^{-1} (7.5, 10.6 and 12.0 cm). The weedy check plot (T_9) recorded the lowest plant height, which might be due to severe competition exerted by grassy and broadleaved weeds throughout the growth period of groundnut by shading effect of weeds or overcrowding in crop-weed ecosystem. This corroborates the results of Kadavkar (1999), Sonwalkar (2005), Jadhav (2007) and Kumawat (2014).

Yield attributes

Number of pods plant^{-1}

The data on number of pods plant^{-1} of groundnut were statistically analysed and presented in table 3. The

Table 1: Effect of treatments on weed density in groundnut

Treatments	Weed density (Number m^{-2})								
	Grassy weed			Broadleaved weed			Sedge weed		
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
T_1: Fomesafen + fluazifop-p-butyl @ 100+100g ha^{-1}	1.05 (0.66)	1.54 (1.89)	2.12 (3.99)	1.24 (1.04)	1.49 (1.74)	2.35 (5.03)	1.05 (0.66)	1.37 (1.59)	1.89 (3.11)
T_2: Fomesafen + fluazifop-p-butyl @ 125+125 g ha^{-1}	0.85 (0.25)	0.93 (0.47)	1.76 (2.61)	0.90 (0.38)	0.98 (0.60)	2.04 (3.65)	0.84 (0.24)	0.98 (0.61)	1.5 (1.82)
T_3: Fomesafen + fluazifop-p-butyl @ 150+150 g ha^{-1}	0.83 (0.22)	0.92 (0.44)	1.76 (2.60)	0.85 (0.25)	0.96 (0.55)	2.02 (3.57)	0.95 (0.42)	1.04 (0.63)	1.46 (1.67)
T_4: Fomesafen + fluazifop-p-butyl @ 175+175 g ha^{-1}	0.71 (0.00)	0.90 (0.38)	1.71 (2.43)	0.71 (0.00)	0.92 (0.44)	1.94 (3.27)	0.81 (0.17)	0.97 (0.48)	1.4 (1.48)
T_5: Fomesafen + fluazifop-p-butyl @ 250+250 g ha^{-1}	0.71 (0.00)	0.89 (0.36)	1.60 (2.10)	0.71 (0.00)	0.91 (0.42)	1.87 (2.99)	0.8 (0.16)	0.90 (0.36)	1.29 (1.22)
T_6: Imazethapyr @ 100.0 g ha^{-1}	0.85 (0.27)	1.06 (0.88)	1.87 (2.98)	2.12 (3.99)	3.75 (13.56)	5.2 (26.62)	1.1 (0.78)	1.24 (1.17)	1.74 (2.54)
T_7: Fluazifop-p-butyl + fomesafen@ 125+125 g ha^{-1}	1.01 (0.58)	1.22 (1.15)	2.00 (3.49)	1.05 (0.66)	1.39 (1.46)	2.31 (4.81)	1.03 (0.62)	1.29 (1.2)	1.69 (2.41)
T_8: Hand Weeding at 15 and 30 DAS	1.25 (1.05)	1.29 (1.16)	1.66 (2.25)	1.29 (1.16)	1.28 (1.15)	1.44 (1.57)	1.21 (0.98)	1.22 (1.00)	1.52 (1.85)
T_9: Weedy check	2.41 (5.32)	3.77 (13.71)	4.38 (18.75)	4.04 (15.8)	5.93 (34.64)	7.74 (59.52)	2.41 (5.32)	3.4 (11.08)	4.01 (15.6)
T_{10}:Weed free check	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
SEm (±)	**0.12**	**0.20**	**0.05**	**0.11**	**0.16**	**0.08**	**0.12**	**0.18**	**0.12**
LSD (0.05)	**0.35**	**0.60**	**0.16**	**0.33**	**0.48**	**0.25**	**0.35**	**0.55**	**0.35**

Figures in parentheses are the original values. The data was transformed to SQRT (X+0.5) before analysis

Table 2: Effect of treatments on dry weight of weeds in groundnut

Treatments	**Dry weight (g m^{-2})**								
	Grassy weed			**Broadleaved weed**			**Sedge weed**		
	30 DAS	**45 DAS**	**60 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**30 DAS**	**45 DAS**	**60 DAS**
T_1: Fomesafen + fluazifop-p-butyl @ 100+100g ha^{-1}	0.74 (0.04)	0.91 (0.32)	1.4 (1.46)	0.75 (0.06)	0.88 (0.28)	1.23 (1.02)	0.76 (0.08)	0.95 (0.43)	1.45 (1.63)
T_2: Fomesafen + fluazifop-p-butyl @ 125+125 g ha^{-1}	0.71 (0.01)	0.77 (0.1)	1.23 (1.02)	0.72 (0.02)	0.76 (0.08)	1.07 (0.64)	0.73 (0.03)	0.81 (0.17)	1.14 (0.8)
T_3: Fomesafen + fluazifop-p-butyl @ 150+150 g ha^{-1}	0.72 (0.01)	0.76 (0.09)	1.28 (1.14)	0.72 (0.02)	0.75 (0.06)	1.12 (0.75)	0.74 (0.05)	0.86 (0.25)	1.15 (0.84)
T_4: Fomesafen + fluazifop-p-butyl @ 175+175 g ha^{-1}	0.71 (0.00)	0.75 (0.07)	1.27 (1.11)	0.71 (0.00)	0.73 (0.04)	1.06 (0.62)	0.72 (0.02)	0.80 (0.14)	1.1 (0.71)
T_5: Fomesafen + fluazifop-p-butyl @ 250+250 g ha^{-1}	0.71 (0.00)	0.74 (0.05)	1.16 (0.84)	0.71 (0.00)	0.73 (0.03)	1.01 (0.53)	0.72 (0.02)	0.79 (0.13)	1.04 (0.59)
T_6: Imazethapyr @ 100.0 g ha^{-1}	0.73 (0.03)	0.83 (0.21)	1.37 (1.37)	0.84 (0.2)	1.31 (1.22)	2.36 (5.06)	0.77 (0.1)	0.97 (0.47)	1.35 (1.35)
T_7: Fluazifop-p-butyl + fomesafen@ 125+125 g ha^{-1}	0.73 (0.04)	0.86 (0.25)	1.53 (1.87)	0.73 (0.04)	0.8 (0.14)	1.2 (0.95)	0.76 (0.08)	0.95 (0.4)	1.42 (1.5)
T_8: Hand Weeding at 15 and 30 DAS	0.73 (0.04)	0.87 (0.25)	1.19 (0.93)	0.74 (0.05)	0.81 (0.16)	0.99 (0.48)	0.75 (0.07)	0.89 (0.30)	1.2 (0.95)
T_9: Weedy check	0.97 (0.45)	1.83 (2.85)	2.91 (7.98)	1.2 (0.95)	1.93 (3.21)	3.17 (9.59)	1.08 (0.67)	1.79 (2.7)	2.36 (5.05)
T_{10}:Weed free check	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
SEm (±)	**0.01**	**0.06**	**0.05**	**0.01**	**0.03**	**0.04**	**0.02**	**0.07**	**0.07**
LSD (0.05)	**0.04**	**0.17**	**0.15**	**0.03**	**0.08**	**0.13**	**0.06**	**0.22**	**0.19**

Figures in parentheses are the original values. The data was transformed to SQRT (X+0.5) before analysis

Table 3: Effect of treatments on plant height, number of pods, number of kernel and 100 kernel weight of groundnut

Treatments	Plant height (cm)			Number of pods plant^{-1}	Number of kernels pod^{-1}	100 kernel weight (g)
	30 DAS	45 DAS	60 DAS			
T_1: Fomesafen + fluazifop-p-butyl @ 100+100g ha^{-1}	8.0	10.9	12.7	13.1	14.7	16.6
T_2: Fomesafen + fluazifop-p-butyl @ 125+125 g ha^{-1}	8.6	11.9	13.3	14.1	16.4	18.9
T_3: Fomesafen + fluazifop-p-butyl @ 150+150 g ha^{-1}	8.8	12.0	13.3	14.2	16.3	18.8
T_4: Fomesafen + fluazifop-p-butyl @ 175+175 g ha^{-1}	8.8	12.2	13.6	14.4	16.5	19.3
T_5: Fomesafen + fluazifop-p-butyl @ 250+250 g ha^{-1}	8.9	12.7	13.7	14.7	17.3	20.3
T_6: Imazethapyr @ 100.0 g ha^{-1}	7.5	10.6	12.0	12.6	15.4	16.4
T_7: Fluazifop-p-butyl + fomesafen@ 125+125 g ha^{-1}	8.6	11.8	13.0	13.6	15.3	16.5
T_8: Hand Weeding at 15 and 30	8.6	11.0	12.6	13.8	15.5	16.9
DAST$_9$: weedy check	7.2	8.9	9.7	9.9	10.8	11.3
T_{10}:Weed free check	9.6	12.8	13.8	15.2	17.9	20.9
SEm (±)	**0.40**	**0.54**	**0.69**	**0.80**	**0.85**	**0.85**
LSD (0.05)	**1.18**	**1.59**	**2.04**	**2.36**	**2.52**	**2.52**

Table 4: Effect of treatments on pod yield, kernel yield, harvest index and weed index of groundnut

Treatments	Pod yield (kgha^{-1})	Kernel yield (ha^{-1})	Harvest index(%)	WI %)
T_1: Fomesafen + fluazifop-p-butyl @ 100+100g ha^{-1}	1401	936	37.86	35.71
T_2: Fomesafen + fluazifop-p-butyl @ 125+125 g ha^{-1}	1887	1139	39.92	16.39
T_3: Fomesafen + fluazifop-p-butyl @ 150+150 g ha^{-1}	1892	1283	40.30	16.10
T_4: Fomesafen + fluazifop-p-butyl @ 175+175 g ha^{-1}	2036	1419	38.09	6.50
T_5: Fomesafen + fluazifop-p-butyl @ 250+250 g ha^{-1}	2009	1447	38.76	7.65
T_6: Imazethapyr @ 100.0 g ha^{-1}	1177	836	37.79	45.93
T_7: Fluazifop-p-butyl + fomesafen@ 125+125 g ha^{-1}	1243	872	38.38	42.91
T_8: Hand Weeding at 15 and 30 DAS	1363	955	36.09	37.57
T_9: weedy check	549	395	32.91	74.78
T_{10}:Weed free check	2177	1727	41.61	0.00
SEm (±)	**92**	**101**	**1.27**	**-**
LSD (0.05)	**274**	**299**	**3.78**	**-**

Table 5: Weed control efficiency of different treatments against weeds in groundnut

Treatments	WCE (%)								
	Grassy weed			Broadleaved weed			Sedge weed		
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
T_1: Fomesafen + fluazifop-p-butyl @ 100+100g ha^{-1}	90.7	88.7	81.4	93.4	91.3	89.2	87.7	83.8	67.7
T_2: Fomesafen + fluazifop-p-butyl @ 125+125 g ha^{-1}	97.9	96.7	87.1	98.3	97.6	93.2	95.5	93.5	83.7
T_3: Fomesafen + fluazifop-p-butyl @ 150+150 g ha^{-1}	96.9	96.9	85.5	98.1	98.1	92.1	92.1	90.6	83.0
T_4: Fomesafen + fluazifop-p-butyl @ 175+175 g ha^{-1}	100.0	97.5	86.0	100.0	98.7	93.4	96.9	94.7	85.8
T_5: Fomesafen + fluazifop-p-butyl @ 250+250 g ha^{-1}	100.0	98.1	89.5	100.0	99.0	94.4	97.1	95.3	88.3
T_6: Imazethapyr @ 100.0 g ha^{-1}	93.5	92.6	82.7	79.0	61.9	46.5	85.2	82.8	73.0
T_7: Fomesafen + fluazifop-p-butyl @ 125+125 g ha^{-1}	92.1	91.1	76.2	95.9	95.6	90.0	88.4	85.0	70.1
T_8: Hand Weeding at 15 and 30 DAS	92.1	91.2	88.3	95.1	95.1	95.0	90.0	88.9	81.1
T_9: Weedy check	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T_{10}:Weed free check	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 6: Effect of treatments on economics of groundnut production

Treatments	Economics			
	Cost of cultivation (^{1} ha^{-1})	Gross return (^{1} ha^{-1})	Net return (^{1} ha^{-1})	B:C
T_1: Fomesafen + fluazifop-p-butyl @ 100+100g ha^{-1}	30171	71207	41036	2.36
T_2: Fomesafen + fluazifop-p-butyl @ 125+125 g ha^{-1}	30212	95798	65587	3.17
T_3: Fomesafen + fluazifop-p-butyl @ 150+150 g ha^{-1}	30253	95988	65735	3.17
T_4: Fomesafen + fluazifop-p-butyl @ 175+175 g ha^{-1}	30294	103432	73138	3.41
T_5: Fomesafen + fluazifop-p-butyl @ 250+250 g ha^{-1}	30417	102054	71637	3.36
T_6: Imazethapyr @ 100.0 g ha^{-1}	30192	59815	29624	1.98
T_7: Fomesafen + fluazifop-p-butyl @ 125+125 g ha^{-1}	30212	63157	32946	2.09
T_8: Hand Weeding at 15 and 30 DAS	48007	69364	21357	1.44
T_9: weedy check	30007	27995	-2011	0.93
T_{10}:Weed free check	84007	110384	26378	1.31
SEm (±)	—	**4683**	**4683**	**0.13**
LSD (0.05)	—	**13913**	**13913**	**0.38**

maximum number of pods plant^{-1} was recorded with T_{10}- weed free (21.5). The minimum number of pods plant^{-1} was recorded with T_9- weedy check (12.5) which was significantly lower than other weed management treatments. Among herbicidal treatment, T_4- fomesafen + fluazifop-p-butyl @175+175 g ha^{-1} recorded maximum number of pods plant^{-1} (20.5) followed by T_5- fomesafen + fluazifop-p-butyl @250+250 g ha^{-1} (19.6), T_3- fomesafen + fluazifop-p-buyl@150+150 g ha^{-1} (19.1), T_2- fomesafen + fluazifop-p-butyl @125+125 g ha^{-1} (18.5), T_7- fluazifop-p-butyl+fomesafen@125+125 g ha^{-1} (18.1), T_1- fomesafen + fluazifop-p-butyl at 100+100 g ha^{-1} (17.1) and T_6- Imazethapyr at 100.0 g ha^{-1} (15.8). This might be due to efficient and timely weed management practices by application of herbicide effectively controlled different spectrum of weeds appearing in different flushes during the crop growth period and thereby promoted pods formation of groundnut. Thus groundnut faced limited or no weed competition during its critical period that facilitated better growth and higher leaf area and dry matter accumulation for pod development. Similar findings were also reported by Rafey and Prasad, (1995), Malik (2013) and Kumawat (2014).

Number of kernels pod^{-1} and 100 kernel weight

The results showed that maximum number of kernels pod^{-1} and 100 kernel weight of groundnut was recorded with T_4- Fomesafen + fluazifop-p-butyl @175+175 g ha^{-1} (3.0 and 51.6 g) followed by T_{10}- weed free (3.0 and 51.0 g) whereas minimum number of kernels pod^{-1} and 100 kernel weight of groundnut was recorded with T_9- weedy check (1.6 and 43.8 g) in table 3. Among herbicidal treatment, the second best treatment was T_5- fomesafen + fluazifop-p-butyl @250+250 g ha^{-1} (3.0 and 51.1 g) followed by T_3-fomesafen + fluazifop-p-buyl@150+150 g ha^{-1} (3.0 and 49.8 g), T_2- fomesafen + fluazifop-p-butyl @125+125 g ha^{-1} (3.0 and 48.7 g), T_6- Imazethapyr@ 100.0 g ha^{-1} (2.4, 48.7 g), T_1- fomesafen + fluazifop-p-butyl @100+100 g ha^{-1} (2.7, 47.7 g) and T_7- fluazifop-p-butyl+fomesafen@125+125 g ha^{-1} (2.3, 47.6 g). These treatments controlled all spectrum of weed effectively as evident from the data on weed density, weed dry weight and weed control efficiency. The competition between groundnut and weeds was minimum, which helped enhancing growth attributes and partitioning of dry matter towards kernel formation. The results corroborate the findings of Jadhav (2007), Kumawat (2014) and Malik (2013).

Pod yield, kernel yield and harvest index

The analysed data on pod yield, kernel yield and harvest index of groundnut were presented in table 4. The maximum pod yield (2177 kg ha^{-1}), kernel yield (1727 kg ha^{-1}) and harvest index (41.61%) of groundnut was recorded with T_{10}- weed free whereas minimum pod yield (549 kg ha^{-1}), kernel yield (395 kg ha^{-1}) and harvest index (32.91%) of groundnut was recorded with T_9- weedy check which was significantly lower than other weed management treatments. Among herbicidal treatment, T_4- fomesafen + fluazifop-p-butyl @175+175 g ha^{-1} recorded maximum pod yield (2036 kg ha^{-1}) followed by T_5- fomesafen + fluazifop-p-butyl @250+250 g ha^{-1} (2009 kg ha^{-1}), T_3-fomesafen + fluazifop-p-buyl@150+150 g ha^{-1} (1892 kg ha^{-1}), T_2- fomesafen + fluazifop-p-butyl @125+125 g ha^{-1} (1887 kg ha^{-1}), T_1- fomesafen + fluazifop-p-butyl @100+100 g ha^{-1} (1401 kg ha^{-1}), T_7- fluazifop-p-butyl+fomesafen@125+125 g ha^{-1} (1243 kg ha^{-1}) and T_6- imazethapyr@ 100.0 g ha^{-1} (1177 kg ha^{-1}). The higher pod yield with herbicidal treatment might be due to control of whole spectrum of weeds effectively as evident from the data on weed density, weed dry weight and weed control efficiency. The competition between groundnut and weeds for nutrient, moisture, light and space was less under the above treatments, which facilitated greater harvesting of sun light, higher synthesis of carbohydrate and better partitioning of photosynthates towards pod formation and ultimately leading to higher pod yield of ground nut. Similar beneficial effect of weed management practices on ground nut yield was reported by Bhagat (1997), Madhavi *et al.* (2008), Kumawat (2014) and Malik (2013). Weedy check reduced seed yield due to increased crop weed competition for natural resources like soil moisture, nutrients and light. Similar yield reduction due to presence of weeds has been reported by Hiremath *et al.* (1997) and Kori (2000). Similarly, among herbicidal treatments, T_5- fomesafen + fluazifop-p-butyl @250+250 g ha^{-1} recorded maximum kernel yield (1447 kg ha^{-1}) followed by T_4- fomesafen + fluazifop-p-butyl @ 175+175 g ha^{-1} (1419 kg ha^{-1}) ,T_3- fomesafen + fluazifop-p-buyl@150+150 g ha^{-1} (1263 kg ha^{-1}), T_2- fomesafen + fluazifop-p-butyl @125+125 g ha^{-1} (1139 kg ha^{-1}), T_1- fomesafen + fluazifop-p-butyl @100+100 g ha^{-1} (936 kg ha^{-1}), T_7- fluazifop-p-butyl+fomesafen@125+125 g ha^{-1} (872 kg ha^{-1}) and T_6- imazethapyr@ 100.0 g ha^{-1} (836 kg ha^{-1}). The increase in kernel yield with herbicidal treatment might be due to higher pod yield as well as control of whole spectrum of weeds effectively as evident from the data on weed density, weed dry weight and weed control efficiency. Similar beneficial effect of weed management practices on ground nut yield was reported by Ambulkar *et al.* (1993), Waghmode (1996), Bhagat (1997), Bhale *et al.* (2012) and Kumawat (2014).

Weed control efficiency

The data on weed control efficiency against total grassy,broadleaved and sedge weed recorded at 30, 45 and 60 days after sowing of ground nut were statistically analysed and presented in table 5. The result showed that the highest weed control efficiency against total grassy weed was recorded with T_{10} – weed free treatment (100 per cent) at 30, 45 and 60 DAS. In case of grassy weed, among the herbicidal treatments higher weed control efficiency was recorded with T_5-fomesafen + fluazifop-p-butyl @250+250 g ha^{-1}(100, 98.1 and 89.5 %) followed by T_4- Fomesafen + fluazifop-p-butyl @175+175 g ha^{-1}(100, 97.5 and 86.0 %), T_2- Fomesafen + fluazifop-p-butyl @125+125 g ha^{-1} (97.9, 96.7 and 87.1%) and T_3-fomesafen + fluazifop-p-buyl@150+150 g ha^{-1} (96.9, 96.9 and 85.5%).Weed control efficiency against broadleaved and sedge weed is similar to grassy weed. Even all fomesafen + fluazifop-p-butyl except fomesafen + fluazifop-p-butyl at 100+100 g ha^{-1} recorded higher weed control efficiency against grassy, broadleaved and sedge weed than all the standard checks used in this experiment. The difference between fomesafen + fluazifop-p-butyl and hand weeding is marginal because their dry weight was at par in table 2. T_9- weedy check recorded lowest weed control efficiency against total grassy, broad leaved and sedge weed (0.00 %).

Weed index

Weed index (Table 4) expressed that any type of herbicides recorded lower weed index over that of T_9-unweeded check. Among herbicidal treatment the lowest value of weed index was recorded with T_4- Fomesafen + fluazifop-p-butyl at 175+175 g ha^{-1} (6.50 %) followed by T_5-Fomesafen + Fluazifop-p-butyl at 250+250 g ha^{-1} (7.65 %), T_3-fomesafen + fluazifop-p-buyl at 150+150 g ha^{-1} (16.10%), T_2- Fomesafen + fluazifop-p-butyl at 125+125 g ha^{-1} (16.39 %), T_1- Fomesafen + fluazifop-p-butyl at 100+100 g ha^{-1} (35.71 %), T_7- fluazifop-p-butyl+fomesafenat 125+125 g ha^{-1} (42.91 %) and T_6-imazethapyr at 100.0 g ha^{-1} (45.93%). Similar opinion was also put forwarded by Kumawat (2014) and Malik (2013).

Economics

All the weed control treatments recorded higher net returns and B:C ratio over weedy check (Table 6). Among herbicidal treatments higher net returns (¹ 71185 ha^{-1}) and B:C (3.21) ratio was recorded in T_4- Fomesafen + fluazifop-p-butyl at 175+175 g ha^{-1} closely followed by T_5- Fomesafen + Fluazifop-p-butyl at 250+250 g ha^{-1} (¹ 68848 ha^{-1} and 3.07), T_2- Fomesafen + fluazifop-p-butyl at 125+125 g ha^{-1} (¹ 64192 ha^{-1} and 3.03), T_3-fomesafen + fluazifop-p-buyl at 150+150 g ha^{-1} (¹ 64061 ha^{-1} and 3.01), T_1- Fomesafen + fluazifop-p-butyl at 100+100 g ha^{-1} (¹ 39921 ha^{-1} and 2.28), T_7- fluazifop-p-butyl+fomesafenat 125+125 g ha^{-1} (¹ 31551 ha^{-1} and 2.00) and T_6- imazethapyr at 100.0 g ha^{-1} (¹ 28509 ha^{-1} and 1.91) whereas minimum net returns (¹ 2011 ha^{-1}) and B:C (0.93) was recorded with T_9- weedy check. This was due to higher pod yield and subsequently lower cost of cultivation (Mene *et al.*, 2003) of groundnut crop which was increased in treatment weed free due to the higher need of human labours and their higher wages. This cost was reduced might be due to use herbicides that effectively control of weeds with decreasing human labours. Sasikala *et. al.* (2004) and Rao *et al.* (2011) have also reported that higher net return and B:C ratio with application of herbicides. On the other hand, weedy check recorded lower net returns and B:C ratio. Tewari *et al.* (1989) reported that the additional amount of income gained under weed free seemed to be immaterial over cost of weeding incurred to maintain weed free condition beyond eight weeks after sowing. The availability of working forces in rural areas has been reduced considerably and accessibility to require labour forces at specific stage of crop growth is also challenging.

From the present investigation it can be concluded that fomesafen + fluazifop-p-butyl @125+125 g ha^{-1} appeared as effective and economic for managing broad spectrum weeds of groundnut and to reduce considerable loss in yield in lateritic soil of West Bengal.

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