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Growth, yield and economics in summer groundnut sequenced with rice under different weed management options

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ABSTRACT

A field experiment was conducted during three consecutive summer seasons of 2016-17, 2017–2018 and 2018-2019 in sandy clay loam soil at the Research Farm, Bidhan Chandra Krishi Viswavidyalaya, West Bengal to study the effect of different weed control methods in summer groundnut. The experiment comprising six treatments was replicated four times in a randomized block design. The pre-emergence application (PE) of pendimethalin 1.5 kg/ha followed by post-emergence application (PoE) of imazethapyr 75 g/ha was found to be the most effective in controlling weeds, and resulted in higher groundnut growth and yield attributes, higher pod yield (2.76 t/ha) and maximum BCR (2.65) than other treatments in summer groundnut crop grown in sequence with rice.

INTRODUCTION

Groundnut (*Arachis hypogea* L.) is one of the most important oilseed crops cultivated for edible oil, protein and confectionery purpose (Vora *et al.* 2019). India has a diverse climate and groundnut is grown throughout the year in one part or the other in the country. The productivity of groundnut under irrigated condition is not stable due to various constrains. Among them weed infestation is considered to be the most important limiting factor in achieving potential productivity of groundnut (Patel *et al.* 2020). Yield losses due to heavy weed infestation in groundnut ranged from 13-80% in India (Ghosh *et al.* 2000). Unlike other crops, weeds interfere with pegging, pod development and harvesting of groundnut besides competing for resources. The crop-weed competition remains maximum during the early stages, especially in bunch-type varieties because of its slow-seedling emergence and initial growth, small foliage cover, prostrate growth habit and consequently poor competitive ability (Sheoran *et al.* 2015). Hand weeding is becoming costlier day by day due to higher wages and non-availability of labour in time particularly at critical period of crop weed competition. Therefore, alternate weed management options and safer herbicides are one of the better substitutes of costly hand weeding (Poddar *et al.* 2017a). Use of different pre- and post-emergence herbicides offers an alternative viable option for effective and timely control of weeds in groundnut. But each herbicide has its own spectrum of weed control (Kundu *et al.* 2020). The pre-emergence application (PE) of herbicides like pendimethalin was found to be effective in controlling the weeds during early stages of crop growth but late flushes and escaped/regenerated weeds in later stages also hamper the crop yield to certain extent possible (Dayal 2004). It necessitates the use of an alternative cost-effective integrated weed-management strategy involving application of both the PE and post-emergence application (PoE) of herbicides in combination with manual or mechanical weeding which will be economical and have least impact on environment and non-target organisms. Thus, the present study was carried out to find out the best weed management practices in groundnut for managing weeds and attain higher productivity of groundnut in rice-groundnut cropping system.

MATERIALS AND METHODS

The experiment was carried out at the Research Farm, Bidhan Chandra Krishi Vishwavidyalaya, West Bengal, India (22°97´ N latitude and 88°43' E longitude with the 9.75 m above the msl). Topographically the land was medium in slope having deep tube well facility and natural weed infestations in summer groundnut during three consecutive year 2016-17, 2017–2018 and 2018-2019. The soil of the experimental site was sandy clay loam (sand 64.8%, silt 10.4%, and clay 24.8%) with a pH of 7.2 and an electrical conductivity of 0.294 ds/m. It contained 0.61% organic C, 177.6 kg available N/ha, 24.3 kg

available P/ha and 147.5 kg available K/ha. The climate of the study site was sub-tropical humid. A combination of six treatments, *viz.* weedy check, weed free check, hand weeding (HW) twice at 20 and 40 days after sowing (DAS), pendimethalin 1.5 kg/ha PE followed by (*fb*) one HW at 20 DAS, pendimethalin 1.5 kg/ha PE *fb* quizalofop-p-ethyl 50 g/ha PoE at 20 DAS and pendimethalin 1.5 kg/ha PE *fb* imazethapyr 75 g/ha PoE at 20 DAS, were evaluated in a randomized block design with four replications. Groundnut '*TG51*' was sown at 30 x 10 cm spacing on 3 x 5 m (15 m^2) area in the mid of February in each of the experimental year. Herbicides were applied using spray volume of 400 litres/ha. The recommended dose of fertilizers, *i.e.*, 20 kg N, 60 kg P and 40 kg K/ha were applied before sowing in the seed row zone using Urea, SSP and MOP, respectively. Different categories of individual weeds (grass, sedge and broad-leaved) were counted individually from each plot. Weed population (density) and weed dry matter (biomass) g/m^2 was measured using a quadrat of 0.5 x 0.5 m. The quadrat was thrown randomly at three places in each plot at 20 DAS and 40 DAS and the weeds were counted category-wise and total weed density was calculated. After counting, the weed samples were uprooted washed in tap water and sundried for two days and then kept in an oven at 70 ± 5°C for 48 h for recording weed dry biomass. Weed control efficiency (WCE) (Mani *et al.* 1973), weed persistence index (WPI) (Mishra and Mishra 1997), herbicide efficiency index (HEI) (Mishra and Mishra 1997), weed index (WI) (Mishra and Mishra 1997), crop resistance index (CRI) (Mishra and Mishra 1997) and weed management index (WMI) (Mishra and Mishra 1997) were calculated using the following equations:

$$\text{WCE} = \frac{\text{WDMc} - \text{WDMt}}{\text{WDMc}}$$

Where, WDMc is the weed biomass (g/m^2) in control plot; WDMt is the weed biomass (g/m^2) in treated plot.

$$\text{WPI} = \frac{\text{WDMt}}{\text{WDMc}} \times \frac{\text{WDc}}{\text{WDt}}$$

Where, WDc is Weed density in control plot; WCt = Weed density in treated plot.

$$\text{HEI} = \frac{\text{Yt} - \text{Yc}}{\text{Yt}} \times \frac{\text{WDMc}}{\text{WDMt}}$$

Where, Yt is crop yield from the treated plot; Yc is crop yield from the control plot; WDMc is the weed biomass (g/m^2) in control plot; WDMt is the weed biomass (g/m^2) in treated plot.

$$\text{WI} = \frac{\text{Yf} - \text{Yt}}{\text{Yf}} \times 100$$

Where, Yf is yield from weed-free plot; Yt is yield from treated plot.

$$\text{CRI} = \frac{\text{CDMt}}{\text{CDMc}} \times \frac{\text{WDMc}}{\text{WDMt}}$$

Where, CDMt is groundnut crop dry matter (g/m^2) in treated plot; CRMc is groundnut crop dry matter (g/m^2) in control plot.

$$\text{WMI} = \frac{\text{Per cent yield over control}}{\text{Per cent control of weeds}}$$

Plant height, dry matter, LAI, nodulation number and other growth and yield parameter were recorded as per standard protocol. The crop harvested from the net plot was taken to threshing floor, dried, threshed and pods were weighed to obtained the pod yield plot wise. These observations were then used to get the pod yield in kg/ha at 14% moisture content.

The harvest index (HI) was calculated by using the formula given by Donald (1963).

$$\text{HI (\%)} = \frac{\text{Groundnut pod yield}}{\text{Total biological yield}} \times 100$$

Mean values of three years' data on crops and weeds were jointly analyzed using the analysis of variance (ANOVA) technique as suggested by Gomez and Gomez (1984). All the collected data were analyzed statistically by the analysis of variance (ANOVA) technique using the SAS Windows Version 9.3. The values wherever necessary were transformed into square root values as applicable for respective statistical analyses (Panse and Sukhatme 1978).

RESULTS AND DISCUSSION

Effect on groundnut crop growth and yield

The growth parameter like plant height, dry matter accumulation, nodulation number were significantly higher in weed free at all growth stage where as the lowest values were recorded in weedy check (**Table 1**). There was no significant variation in plant height at maturity in different treatments except for weed check (42.2 cm), in which the plant height was slightly lower than the rest of the treatments. The groundnut dry matter accumulation in weed free was significantly higher (328.12 g/m^2) which was 38.98% more than that of weedy check. Pendimethalin PE *fb* imazethapyr PoE was equally effective as weed free and there was no significant variation with hand weeding twice. There was 25.42% to 38.98% higher

dry matter accumulation in groundnut due to different weed management approaches. Weed management created a favourable environment for the crop plant and helped to uptake more available resources and ultimately it reflected in its growth parameter (Poddar *et al.* 2017b). Number of nodules/plant and leaf area index (LAI) also followed the similar trends where higher number of nodules and LAI were observed in different weed management treatments as compared with weedy check. Variation in nodules number and LAI due to different weed management was also reported previously by Adhikary *et al.* (2016) and Choudhary *et al.* (2017). Crop growth rate (CGR) was comparatively higher in all the herbicidal treatments and among them pendimethalin PE *fb* imazethapyr PoE and pendimethalin PE *fb* quizalofop-p-ethyl PoE attained the maximum value (4.10 g/m^2/ day). Lowest CGR was in weedy check (2.47 g/m^2/ day). Similar results were also reported earlier by Olayinka and Etejere (2015).

Yield attributing characters like number of pods / plant, shelling %, 100 kernel weight (KW) varied significantly due to different weed management treatments (**Table 2**). Weed free recorded the highest number of pods/plant (25.3) whereas weedy check was the lowest number (13.7) and both of these were significantly different with each other. Among different treatments, HW twice at 20 and 40 DAS followed by pendimethalin 1.5 kg/ha as PE *fb* 1 HW at 20 DAS have recorded higher pods number/plant. There was no significant difference among the various treatments for shelling % and 100 KW but the highest value was found in weed free followed by HW twice. There was an increase of 24.98% to 37.07% groundnut pod yield with different weed management treatments when compared with weedy check. Pod yield and haulm yield varied significantly due to different weed management treatments (**Table 2**). The weed free check was significantly superior in recording highest pod yield (2.96 t/ha) which was followed by pendimethalin 1.5 kg/ha *fb* imazethapyr 75 g/ha at 20 DAS > two HW at 20 and 40 DAS > pendimethalin 1.5 kg/ha *fb* quizalofop-p-ethyl 50 g/ha at 20 DAS in the order of decreasing groundnut pod yield. However, all the herbicidal treatments were statistically at par in terms of pod yield. Weedy check recorded statistically lowest pod yield (2.16 t/ha). Harvest index did not differ significantly amongst the various treatments. Weed free environment helped the crop plants to grow more vigorously and thus crop produces more yield attributing parameter which ultimately turns into higher yield (Poddar *et al.* 2014). The regression equation predicted linear reduction in

Table 1. Effect of different weed control treatments on growth attributes of summer groundnut (pooled analysis)

Treatment	Plant height at harvest (cm)	Dry matter production (g/m^2)		Nodulation (no./plant)		LAI (%) at harvest	CGR (g/m^2 day)
		45 DAS	75 DAS	45 DAS	75 DAS		
Pendimethalin 1.5 kg/ha PE *fb* 1 HW at 20 DAS	44.3	181.7	296.4	72.0	101.3	2.90	3.83
Pendimethalin 1.5 kg/ha PE *fb* quizalofop-p-ethyl 50 g/ha PoE at 20 DAS	43.6	185.5	308.3	68.3	112.7	2.94	4.10
Pendimethalin 1.5 kg/ha PE *fb* imazethapyr 75 g/ha PoE at 20 DAS	44.5	191.3	314.3	70.7	118.0	3.06	4.10
Hand weeding twice (at 20 and 40 DAS)	43.8	195.2	312.3	80.1	111.3	2.96	3.90
Weed free check	45.2	221.2	328.1	82.7	139.1	3.12	3.57
Weedy check	42.2	162.3	236.1	51.3	80.7	2.74	2.47
LSD (p=0.05)	1.4	6.8	13.6	7.1	8.5	0.28	1.36

Table 2. Effect of different weed control treatments on yield attributes and yields of summer groundnut (pooled analysis)

Treatment	Yield attributes of groundnut			Pod yield (t/ha)				Haulm yield (t/ha)	Harvest index (%)
	No. of pods / plant	Shelling (%)	100 KW (g)	2016-17	2017-18	2018-19	Pooled		
Pendimethalin 1.5 kg/ha PE *fb* 1 HW at 20 DAS	21.1	68.6	44.0	2.66	2.70	2.73	2.70	3.41	44.1
Pendimethalin 1.5 kg/ha PE *fb* quizalofop-p-ethyl 50 g/ha PoE at 20 DAS	18.9	68.1	44.1	2.71	2.69	2.81	2.74	3.46	44.2
Pendimethalin 1.5 kg/ha PE *fb* imazethapyr 75 g/ha PoE at 20 DAS	20.3	69.1	44.1	2.81	2.69	2.79	2.76	3.49	44.2
Hand weeding twice (at 20 and 40 DAS)	22.1	69.0	44.6	2.79	2.73	2.70	2.74	3.44	44.3
Weed free check	25.3	69.9	45.6	3.01	2.96	2.90	2.96	3.66	44.6
Weedy check	13.7	66.1	43.7	2.36	1.99	2.12	2.16	2.81	43.4
LSD (p=0.05)	2.53	NS	NS	0.26	0.41	0.38	0.42	0.53	NS

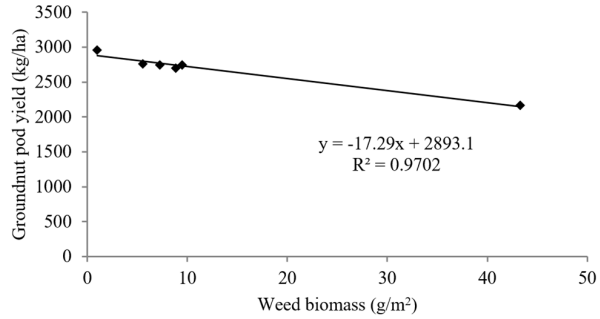

Figure 1. Relationship between groundnut pod yield and weed biomass

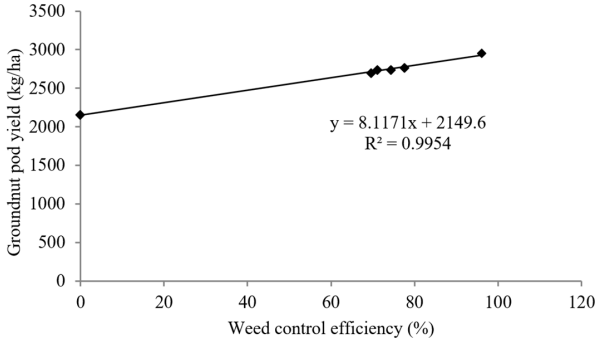

Figure 2. Relationship between groundnut pod yield and weed control efficiency (WCE)

the groundnut pod yield with a unit increase in the dry weight of weeds (**Figure 1**). The extent of reduction of pod yield could be 17.3 kg/ha for weed biomass (kg) per unit m² area. The evaluation of weed control efficiency of the different treatments and the regression of yield on it revealed that 1% increase in the weed control efficiency increased the pod yield by 8.12 kg/ha (**Figure 2**). This is in the conformity of the results reported by Singh *et al.* (2014).

Effect on weeds

All the weed management treatments significantly influenced the weed density and biomass in summer groundnut (**Table 2** and **3**). The dominant weed flora in the experimental site was in the order of broad-leaf weeds (47%) > sedges (32%) > grass (21%) at 20 DAS. The lowest density of different categories of weed (grass, sedges and BLW) was recorded in weed free check whereas maximum in case of weedy check all dates of observation. Among different weed management treatments, there was no significant variation in the weed density of grasses, sedges and BLW, however it was lower in plots treated with pendimethalin PE *fb* imazethapyr PoE at the early growth stage (20 DAS) and HW twice at later stage (40 DAS). Pendimethalin PE *fb* 1 HW at 20 DAS proved statistically at par with pendimethalin 1.5 kg/ha PE *fb* imazethapyr 75 g/ha PoE at 20 DAS in terms of weeds density irrespective of categories and growth stage. Weed biomass accumulation was the reflection of weed density in different treatments (**Table 2**) and the results showed that significantly higher and lower weed biomass was recorded in weedy check and weed free treatment, respectively at all growth stages. There was 69.70% to 77.48% and 79.64% to 84.15% reduction in the total weed biomass accumulation across different weed control treatments at 20 and 40 DAS, respectively. Among different treatments, pendimethalin PE *fb* imazethapyr PoE was found very effective in reducing the total weed biomass and it was statistically at par with HW twice treatment at 20 DAS. Pre-emergence application of pendimethalin helped in controlling early emerged weeds whereas

Table 3. Effect of different weed control treatments on weed density (no./m²) in summer groundnut (pooled analysis)

Treatment	Weed density* (no./m²)						Total weed density (no./m²)	
	Grasses		Sedges		Broad leaved weeds			
	20 DAS	40 DAS	20 DAS	40 DAS	20 DAS	40 DAS	20 DAS	40 DAS
Pendimethalin 1.5 kg/ha PE *fb* 1 HW at 20 DAS	6.4 (2.63)	7.4 (2.81)	11.7 (3.49)	14.2 (3.83)	23.2 (4.87)	22.3 (4.77)	41.3 (6.47)	43.9 (6.66)
Pendimethalin 1.5 kg/ha PE *fb* quizalofop-p-ethyl 50 g/ha PoE at 20 DAS	7.0 (2.74)	7.8 (2.88)	12.0 (3.54)	12.7 (3.63)	27.8 (5.32)	27.9 (5.33)	46.8 (6.88)	48.5 (7.00)
Pendimethalin 1.5 kg/ha PE *fb* imazethapyr 75 g/ha PoE at 20 DAS	7.6 (2.85)	7.7 (2.86)	11.0 (3.39)	12.3 (3.58)	24.1 (4.96)	22.0 (4.74)	42.7 (6.57)	42.0 (6.52)
Hand weeding twice (at 20 and 40 DAS)	8.6 (3.02)	6.1 (2.57)	11.0 (3.39)	11.0 (3.39)	29.2 (5.45)	24.9 (5.04)	48.8 (7.02)	42.0 (6.52)
Weed free check	1.4 (1.38)	1.5 (1.41)	1.9 (1.55)	2.3 (1.67)	5.1 (2.37)	4.1 (2.14)	8.4 (2.98)	7.9 (2.90)
Weedy check	18.1 (4.31)	28.4 (5.38)	27.9 (5.33)	41.1 (6.45)	40.7 (6.42)	85.2 (9.26)	86.7 (9.34)	154.7 (12.46)
LSD (p=0.05)	3.26	3.21	2.41	2.24	1.36	4.80	3.97	5.34

*Data are subjected to square root transformation [$\sqrt{(x+0.5)}$]; values in the parentheses are transformed

late flushes were effectively controlled by post-emergence application of imazethapyr which was clearly reflected in terms of weed density and biomass. Hand weeding was also found effective in controlling all categories of weeds. This is in conformity with the earlier findings of (Patel *et al.* 2020).

Weed indices

Different weed indices varied among the different treatments (**Table 5**) due to difference in their weed management efficacy. WCE was highest in weed free treatment. Pendimethalin PE *fb* imazethapyr PoE and HW twice (at 20 and 40 DAS) were next best in terms of WCE at all the dates of observation. WCE varied between 69.70 to 77.48 % at 20 DAS and 78.04 to 87.15% at 40 DAS among the different herbicidal treatments. WPI also followed the similar trend as like WCE and the descending order was pendimethalin 1.5 kg/ha PE *fb* imazethapyr 75 g/ ha at 20 DAS>two hand weeding (at 20 and 40 DAS)>pendimethalin 1.5 kg/ha *fb* 1 HW at 20 DAS>pendimethalin 1.5 kg/ha *fb* quizalofop-p-ethyl 50 g/ha at 20 DAS. HEI and CRI were higher in weed free treatment which was followed by pendimethalin 1.5 kg/ha PE *fb* imazethapyr 75 g/ha at 20 DAS (0.97 and 5.91, respectively) and then hand weeding twice (0.82 and 5.13, respectively). Weed index was maximum in weedy check and nil in case of weed free treatment. Among the different herbicidal treatments, pendimethalin 1.5 kg/ha PE *fb* imazethapyr 75 g/ha at 20 DAS closely followed by HW twice and then pendimethalin as PE *fb* quizalofop-p-ethyl as PoE were superior in terms of lower value of WI. There was not much variation in WMI among the different treatments although weed free was the best (0.39) followed by pendimethalin PE *fb* quizalofop-p-ethyl PoE (0.38). Variation in weed indices due to different methods of weed management was also reported earlier by Poddar *et al.* (2017a) and Adhikary *et al.* (2016).

Economics

Weedy check treatment resulted in lowest net returns and benefit: cost ratio (BCR) (**Table 5**). Pendimethalin PE *fb* imazethapyr PoE gave the highest net returns and BCR (2.65) and it was on-par with pendimethalin PE *fb* quizalofop-p-ethyl PoE (2.63). Integration of hand-weeding at 20 DAS with pendimethalin significantly improved the groundnut

Table 4. Effect of different weed control treatments on weed biomass (g/m^2) in summer groundnut (pooled analysis)

Treatment	Weed biomass (g/m^2)						Total weed biomass (g/m^2)	
	Grasses		Sedges		BLW			
	20 DAS	40 DAS	20 DAS	40 DAS	20 DAS	40 DAS	20 DAS	40 DAS
Pendimethalin 1.5 kg/ha PE *fb* 1 HW at 20 DAS	1.23	1.46	1.95	2.83	4.18	4.53	7.36	8.82
Pendimethalin 1.5 kg/ha PE *fb* quizalofop-p-ethyl 50 g/ha PoE at 20 DAS	1.01	2.28	1.62	2.13	4.37	5.10	7.0	9.51
Pendimethalin 1.5 kg/ha PE *fb* imazethapyr 75 g/ha PoE at 20 DAS	0.95	0.96	1.20	1.42	3.32	3.19	5.47	5.57
Hand weeding twice (at 20 and 40 DAS)	1.18	0.87	1.16	1.73	3.92	4.66	6.26	7.26
Weed free check	0.14	0.16	0.20	0.36	0.60	0.49	0.94	1.01
Weedy check	5.28	7.78	6.96	12.21	12.05	23.34	24.29	43.33
LSD (p=0.05)	1.05	1.79	0.43	0.88	0.31	1.02	1.79	1.76

Table 5. Effect of different weed control treatments on different weed indices and economics of summer groundnut (pooled analysis)

Treatment	WCE (%)		WPI		HEI	CRI	Weed index (%)	WMI	Total cost (x10^3 `/ha)	Gross return (x10^3 `/ha)	Net return (x10^3 `/ha)
	20 DAS	40 DAS	20 DAS	40 DAS							
Pendimethalin 1.5 kg/ha PE *fb* 1 HW at 20 DAS	69.7	79.6	0.14	0.06	0.66	4.14	8.82	0.36	34.02	84.52	50.51
Pendimethalin 1.5 kg/ha PE *fb* quizalofop-p-ethyl 50 g/ha PoE at 20 DAS	71.2	78.0	0.16	0.07	0.73	4.53	7.47	0.38	32.67	85.77	53.10
Pendimethalin 1.5 kg/ha PE *fb* imazethapyr 75 g/ha PoE at 20 DAS	77.5	87.1	0.11	0.04	0.97	5.91	6.56	0.36	32.67	86.56	53.90
Hand weeding twice (at 20 and 40 DAS)	74.2	83.2	0.15	0.05	0.82	5.13	7.40	0.36	35.67	85.79	50.12
Weed free check	96.1	97.7	0.00	0.00	6.99	35.91	0.00	0.39	36.77	92.64	52.87
Weedy check	0.0	0.0	1.00	1.00	0.00	1.00	27.05	-	31.20	67.48	36.28

pod yield but the profit margin was reduced due to higher wages spent on human labour. Similarly weed free and hand weeding twice also reduced the net return and BCR because of higher wages of human labour. Similar results were reported by Sheoran *et al.* (2015).

Conclusion

Pendimethalin PE *fb* imazethapyr PoE was very effective in managing different categories of weeds and also recording higher groundnut pod yield, net return and BCR. The next best treatment was pendimethalin PE *fb* quizalofop-p-ethyl PoE. Thus, it can be concluded that pendimethalin PE *fb* imazethapyr PoE is most effective for timely control of weeds and produce the higher pod yield and maximum profit in summer groundnut while reducing the labour requirement and cost for weeding.

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