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Integrated weed management for rainfed groundnut

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Abstract: Field experiments were conducted under rainfed conditions in 1987 and 1988 on groundnut (*Arachis hypogaea*) to test the comparative efficacy of pre-emergence herbicides metolachlor [2 chloro-N (2-ethyl 6 methylphenyl)-N (2-methoxy-1 methylethyl) acetamide] and pendimethalin [N (1-ethylpropyl)-3, 4-dimethyl-2,6 dinitrobenzanamine] applied separately, in mixture and in combination with hand weeding The density and dry mass of grass weeds were significantly reduced by herbicide and hand weeding treatments, at all stages of crop growth Integration of herbicides and hand weeding resulted in reduced density and dry mass of broadleaved weeds in comparison with herbicides applied alone Pre-emergence applications of pendimethalin (1 0 kg ha ^{1}) or metolachlor (1.0 kg ha ^{1}) were equivalent to a single hand weeding at 30 days after sowing (DAS) Integration of herbicide and hand weeding at 30 DAS gave consistent and effective weed control and higher pod yields over the two years

Key words: *Arachis hypogaea*, integrated weed control, handweeding, metolachlor, pendimethalin, groundnut

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INTRODUCTION

In groundnut, weeds not only compete for nutrients, light and moisture, but also interfere with farm operations including harvesting (Henning *et al.*, 1982). Being a short statured crop, it is heavily infested by weeds which can reduce crop yields by 25-80% (Naidu *et al.*, 1983). Weed infestation in the rainy season is twice as heavy as in post rainy season (Shanmugam, 1984). Hand weeding is not entirely satisfactory because of narrow row spacing and possible damage to pegs. In addition, with the increasing migration of villagers to urban areas farm labour is becoming expensive and scarce. Chemical weed control can be effective for groundnut if the correct herbicide is applied in appropriate dose, and time (Reddy *et al.*, 1980). However pre-emergence herbicides usually do not provide complete control of weeds since weed emergence does occur at later stages of crop growth and effectiveness is variable (Rathi *et al.*, 1986). Most weed control research has evaluated either chemical or mechanical methods alone. Neither chemical nor mechanical methods alone were adequate for consistent and acceptable weed control, groundnut yield or net returns (Bridges *et al.*, 1984). Hence, integration of chemical and mechanical methods of weed control may be more appropriate and requires further study. The present study was carried out to evaluate the effectiveness of metolachlor and pendimethalin separately, in mixtures, and in combination with manual methods for the control of weeds in groundnut.

MATERIALS AND METHODS

Bunch groundnut cv. Robout 33-1 was grown at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh, India (18°N, 78°E) during the rainy seasons of 1987 and 1988. The soil was an Alfisol (Udic Rhodostalf), sandy clay loam in texture, with a pH of 8.4 and an available water holding capacity of about 100 mm in the top 90 cm of the profile. It contained 19.2 kg ha^{-1} of available inorganic ($NH_4^+ + NO_3^-$) nitrogen (Bremner, 1965), 12.5 kg ha^{-1} of available phosphorus (Olsen and Sommers, 1982) and 158 kg ha^{-1} of potassium (Jackson, 1967). A fertilizer dressing of 18 kg N and 46 kg P_2O_5 ha^{-1} in the form of diammonium phosphate was applied at the time of discing after initial ploughing with a mould board plough. The field was subsequently rotovated and levelled.

The experiment was arranged in a randomized complete block design with three replications. Groundnut was sown in plots of 6.0 m x 9.0 m in rows 30 cm apart at a rate of 100 kg ha^{-1} seed on broad beds of 1.5 m on 26 June 1987 and 21 June 1988. An area of 3.0 m x 6.0 m from the centre of each plot was hand harvested on 28 October 1987 and 13 October 1988. The rainfall received during the crop growth period in 1987 (506 mm) was lower than 1988 (871 mm). The average seasonal rainfall for the location is 760 mm.

The treatments were (i) metolachlor or pendimenthalin at 1.0 and 1.5 kg a.i. ha^{-1}, (ii) a combination of metolachlor and pendimethalin at 1.0 kg a.i. ha^{-1} each; (iii) pre-emergent application of pendimethalin or metolachlor at 1.0 kg a.i. ha^{-1} followed by hand weeding at 30 days after sowing (DAS); and (iv) hand weeding at 30 DAS or at 30 and 45 DAS. A non-weeded control was included. All the herbicides were applied one day after sowing with a knapsack sprayer fitted with a flat fan-type nozzle, using water as a carrier at a volume of 600 l ha^{-1}. Weeds were sampled at 30 and 60 DAS and at harvest within a 1.0 m^2 quadrat and separated into grasses and broadleaves. They were counted, washed and oven dried to estimate the density and dry mass. The data on weed density and dry mass was transformed into $\sqrt{x + 0.5}$ for statistical analysis. Groundnut plant height at 30 and 60 DAS, and pod yields ha^{-1} at maturity were recorded.

The major grass weeds were *Echinochloa colona* (L.) Link., *Urochloa panicoides* Beauv., *Digitaria ciliaris* (Retz.) Koeler. and *Dactyloctenium aegyptium* (L.) P. Beauv. The broadleaved weeds were *Amaranthus viridis* L., *Digera muricata* (L.) Mart., *Celosia argentea* L., *Portulaca oleracea* L., *Lagascea mollis* Cav., *Indigofera glandulosa* Willd., *Trianthema portulacastrum* L., *Eclipta alba* (L.) Hassk. and *Cucumis* sp.

RESULTS AND DISCUSSION

Effect on weeds

The herbicides applied alone and in combination with hand weeding significantly reduced the grass weed density at all stages of crop growth in both years in comparison with the weedy check (Table 1). No differences in grass suppression were observed between various weed management

Table 1. Influence of herbicides and herbicide/manual weeding combinations on total weed density (g m^2).

Treatment	Rate of application (kg a.i ha^{-1})	30 DAS				60 DAS				At harvest			
		1987		1988		1987		1988		1987		1988	
		G	B	G	B	G	B	G	B	G	B	G	B
Metolachlor	1.0	0.0b	5.3c	0.3b	4.0b	20.3b	29.7a	1.3b	4.7b	4 0b	14.0a	5.0bc	18.7b
Metolachlor	1.5	0.7b	7.0c	0.0b	4.3b	2.0c	10.3b	1.7b	2.7b	3.3b	17.3a	3.3bc	13.3bc
Pendimethalin	1.0	3.3b	6.3c	0.0b	9.0b	8.0bc	11.3b	1.3b	6.3b	3.3b	11.7a	3.3bc	12.0bcd
Pendimethalin	1.5	1.0b	5.0c	0.0b	6.3b	5.3c	9.0b	1.3b	5.0b	4.0b	12.7a	3.0bc	11.0bcd
Metolachlor + pendimethalin	1.0 + 1.0	0.3b	2.0c	0.0b	4.7b	4.0c	9.3b	0.7b	6.7b	5.3b	12.7a	2.0c	10.7bcd
Metolachlor + manual weeding at 30 DAS	1.0	0.7b	6.3c	0.0b	6.0b	5.7c	7.7b	0.3b	3.7b	5.0b	9.0a	1.7c	12.0bcd
Pendimethalin + manual weeding at 30 DAS	1.0	1.3b	4.0c	0.3b	7.3b	0.0c	3.0b	0.0b	2.7b	6.0b	10.0a	2.3c	7.3cd
Manual weeding at 30 DAS*	–	96.0a	54.9ab	91.0a	83.0a	8.3bc	9.0b	6.7b	11.7b	14.0b	11.3a	6.3b	18.0bc
Manual weeding at 30 and 45 DAS*	–	82.7a	60.0a	94.7a	75.3a	2.7c	4.0b	2.3b	5.7b	6.7b	13.0a	4.0bc	10.0cd
Weedy check	–	83.3a	46.0b	104.0a	78.3a	52.3a	18.3ab	62.3a	57.3a	146.7a	9.7a	70.7a	48.3a

DAS = Days after sowing; G = Grasses; B = Broadleaved weeds.

Means followed by the same letter within a column are not significantly different at the 5% level using Duncan's multiple range test.

*Treatment imposed after taking the observations, hence similar to weedy check at 30 DAS.

practices at 30 DAS. During 1987, an increase in grass density was observed at 60 DAS with metolachlor at 1.0 kg treatment in comparison with all other weed management practices. However, in 1987 grass densities at harvest were similar regardless of weed management practices, except with hand weeding at 30 DAS. In 1988, there was no difference between the various weed management practices at 60 DAS, except with handweeding given at 30 DAS and grass densities for all treatments were less than the weedy check. However, at harvest significant decreases in grass densities were noted in the treatments with mixture of metolachlor and pendimethalin, metolachlor or pendimethalin in combination with a hand weeding at 30 DAS in comparison with hand weeding alone at 30 DAS.

The broadleaved weeds were effectively controlled up to 30 DAS by all herbicide and herbicide/hand weeding combinations which recorded significantly lower densities in comparison to the weedy check. In 1987, maximum density of broadleaved weeds was recorded with metolachlor (1.0 kg ha^{-1}) at 60 DAS, which was comparable to the weedy check. Broadleaved weed densities in all weed management treatments at harvest were comparable to the weedy check during 1987, but not in 1988. During 1988, all weed management treatments significantly reduced broadleaved weed density in comparison to the weedy check.

Weed species separated at various stages (data not given) indicated increased density of broad leaved weeds such as *E. alba, C. argentea, L. mollis,* and *D. muricata* in all the herbicide treated plots at 60 DAS. This may be attributed to reduced competition from grasses due to the herbicides being more effective on grassy weeds. Application of herbicides in combination with a single or two handweedings reduced broadleaved weed density compared to herbicides applied alone. Thus handweeding was beneficial in removal of herbicide tolerant weeds (*C. argentea, L. mollis, D. celiaris and D. aegyptium*).

The weedy check recorded a significantly higher dry mass of grasses at all the stages. There was no difference among various weed management practices during 1987 and all control treatments recorded significantly lower dry mass of grasses in comparison to the weedy check after first weeding at 30 DAS (Table 2). In 1988, although there was no difference among various weed control practices at 30 DAS, increased dry mass of grasses was observed at 60 DAS and at harvest with handweeding at 30 DAS. However, all the control treatments recorded significantly lower grass dry mass in comparison to the weedy check at all growth stages. There was a reduction in dry mass of broadleaved weeds during 1988 in comparison to 1987 in both herbicide alone and herbicide/handweeding treatments. In 1987, dry mass of broadleaved weeds with metolachlor at 1.0 kg at 60 DAS was as much as in the weedy check and was also comparable to treatments with pendimethalin alone or in mixtures with metolachlor. However, during 1988 all the weed management practices were similar and recorded a significantly lower broadleaved weed dry mass in com-

Table 2. Weed dry mass (g m^{-2}) as influenced by herbicide/manual weeding combinations.

Treatment	Rate of application (kg a.i. ha^{-1})	30 DAS				60 DAS				At harvest			
		1987		1988		1987		1988		1987		1988	
		G	B	G	B	G	B	G	B	G	B	G	B
Metolachlor	1.0	0.0b	1.3c	0.3c	6.7c	41.3b	138.1a	2.3b	5.3b	63.6b	125.5b	2.8b	42.3b
Metolachlor	1.5	0.1b	1.6c	0.4c	3.8c	2.3b	49.6b	1.3b	5.7b	43.3b	70.1b	11.0b	19.3b
Pendimethalin	1.0	0.5b	0.6c	0.0c	8.1c	27.5b	70.8ab	0.4b	8.1b	36.1b	129.0b	20.6b	28.3b
Pendimethalin	1.5	0.9b	0.4c	0.3c	5.1c	4.1b	67.0ab	0.0b	5.3b	44.2b	94.8b	3.8b	24.1b
Metolachlor + pendimethalin	1.0 + 1.0	0.3b	0.3c	0.0c	3.7c	0.7b	83.6ab	0.1b	4.3b	54.4b	81.9b	18.5b	12.8b
Metolachlor + manual weeding at 30 DAS	1.0	0.1b	1.3c	0.0c	8.6c	10.7b	7.7b	0.3b	6.4b	39.7b	45.1b	3.1b	25.5b
Pendimethalin + manual weeding at 30 DAS	1.0	0.2b	0.4c	2.3c	5.5c	0.0b	10.6b	1.1b	5.7b	52.6b	56.6b	2.5b	21.0b
Manual weeding at 30 DAS*	–	6.5b	16.3a	87.8a	84.8b	14.9b	35.5b	11.2b	22.0b	98.1b	76.5b	34.4b	41.7b
Manual weeding at 30 and 45 DAS	–	17.7a	8.3b	59.9b	107.4a	0.6b	3.7b	1.3b	7.2b	35.8b	44.1b	12.8b	24.6b
Weedy check	–	26.2a	9.3b	70.5b	107.9a	571.0a	80.3ab	140.6a	180.2a	304.4a	239.0a	227.4a	222.4a

DAS = Days after sowing; G = Grasses; B = Broadleaved weeds.
Means followed by the same letter within a column are not significantly different at the 5% level using Duncan's multiple range test.
*Treatment imposed after taking the observations, hence similar to weedy check at 30 DAS.

parison to weedy check at 60 DAS. At harvest, all the control treatments recorded a significant reduction in broadleaved weed dry mass in comparison to weedy check during both the years. Among the control treatments, least dry mass of broadleaved weeds was noted with metolachlor in combination with handweeding at 30 DAS and handweeding at 30 and 45 DAS treatments, but these were comparable to all other treatments except metolachlor and pendimethalin alone at 1.0 kg ha^{-1}. However, in 1988 dry mass of broadleaved weeds was least with mixture of metolachlor and pendimethalin treatment but was comparable to metolachlor alone at 1.5 kg, metolachlor or pendimethalin in combination with a handweeding at 30 DAS and handweeding at 30 and 45 DAS treatments. Increased dry mass of broadleaved weeds at 60 DAS during 1987 may be attributed to late rains which favoured the growth and development of *E. alba, C. argentea, L. mollis* and *D. muricata.* These weeds appeared to be relatively less susceptible to pendimethalin and metolachlor. The second flush escaped the weeding due to their late emergence. *C. argentea* appeared to be most aggressive among all the broadleaved weeds.

Treatments having metolachlor alone at 1.5 kg, metolachlor or pendimethalin at 1.0 kg combined with a handweeding, mixture of metolachlor and pendimethalin, and two handweedings at 30 and 45 DAS recorded significantly low weed densities and dry masses during both years.

Brar *et al.* (1980) reported that herbicide activity was apparent only up to 30 DAS when lower herbicide rates (0.75 kg ha^{-1}) were used to control weeds, while Kulandaivelu and Shankaran (1986) observed weed dry mass reduction up to harvest with higher dosage (1.0 - 1.5 kg ha^{-1}) of herbicides. Hence, the rate of herbicide determines the effectiveness and persistence of weed control. Results of the present study confirm that herbicide persistence depends on the rate, but herbicides alone could not control all the weeds. Use of herbicides along with handweeding provided a longer period of weed control in comparison to herbicides alone. The integration of chemical and mechanical methods provided effective and season long weed control.

Effects on crop

Pre-emergence application of pendimethalin and metolachlor at both levels separately or in mixture did not influence either the days to emergence or the plant population of groundnut. No visible phytotoxicity due to herbicides was noted on groundnut plants. Groundnut plant height during 1987 decreased significantly at 30 DAS with the mixture of metolachlor and pendimethalin treatment, but was comparable with weedy check, metolachlor alone at 1.0 or 1.5 kg, pendimethalin at 1.5 kg and pendimethalin in combination with handweeding at 30 DAS. However, at 60 DAS a significant reduction in plant height was observed only in the weedy check (Table 3). In 1988, plant height was significantly reduced in the weedy check and in the mixture of metolachlor and pendimethalin at 30 DAS in comparison with all other treatments, but recovery in plant height was observed at 60 DAS. The total

Table 3. Influence of herbicide/manual weeding combinations on plant height and pod yield of groundnut.

Treatment	Rate of application (kg a.i. ha^{-1})	Plant height (cm) 30 DAS 1987	30 DAS 1988	60 DAS 1987	60 DAS 1988	Pod yield (kg ha^{-1}) 1987	Pod yield (kg ha^{-1}) 1988
Metolachlor	1.0	24.0bc	29.7a	39.0a	39.0a	1152e	1095c
Metolachlor	1.5	24.7abc	29.7a	40.3a	40.0a	1347de	1218bc
Pendimethalin	1.0	25.7ab	30.3a	40.3a	38.7a	1281de	913d
Pendimethalin	1.5	24.7abc	30.0a	41.7a	40.0a	1422cd	1197bc
Metolachlor + pendimethalin	1.0 + 1.0	22.7c	27.7b	39.7a	38.0a	1437cd	1258b
Metolachlor + manual weeding at 30 DAS	1.0	26.3ab	30.3a	41.0a	38.3a	1757ab	1559a
Pendimethalin + manual weeding at 30 DAS	1.0	24.0bc	30.7a	41.7a	38.7a	1602bc	1470a
Manual weeding at 30 DAS*	-	25.0abc	30.0a	41.0a	38.3a	1348de	947d
Manual weeding at 30 and 45 DAS*	-	27.0a	30.7a	41.7a	38.3a	1834a	1174bc
Weedy check	-	24.3bc	27.0b	33.7b	37.7a	429f	442e

DAS = Days after sowing

Means followed by the same letter within a column are not significantly different at the 5% level using Duncan's multiple range test.

*Treatment imposed after taking the observations, hence similar to weedy check at 30 DAS.

weed dry mass of the weedy check was 35 and 178 g m^{-2} at 30 DAS and 651 and 320 g m^{-2} at 60 DAS during 1987 and 1988 respectively (Table 2).

A significant reduction in the height of groundnut due to weed competition was also reported by Rathi *et al.* (1986). The seasonal rainfall was low (506 mm) and less rain was received during the early part in 1987. Although weed growth was less initially, rains during the latter part increased both the density and dry mass of weeds substantially. On the contrary, in 1988 the annual seasonal rainfall was higher (871 mm) and the heavy rains earlier in the season resulted in early intense weed competition. The significant reduction in

groundnut plant height at 30 and 60 DAS in 1987 and at 30 DAS in 1988 in the weedy check may be attributed to rainfall distribution. However, the reduced groundnut plant height with the mixture of metolachlor and pendimethalin at 30 DAS during both the years is attributed to growth retardation due to transient herbicide injury.

The pod yields in the weed management treatments were two to three times higher than the weedy check (Table 3). Short stature and prostrate growth habit makes groundnut a poor competitor with most weeds. Tosh *et al.* (1984) reported that effective control of weeds resulted in improved yield parameters and yield of groundnut. During 1987, maximum pod yields were recorded in treatments with two handweedings, and metolachlor (1.0 kg ha^{-1}) in combination with a handweeding at 30 DAS.

In 1988, metolachlor or pendimethalin at 1.0 kg followed by a handweeding and the mixture of metolachlor and pendimethalin treatments recorded higher yields when compared to the other treatments. Increase in number of pods, pod mass and stover yields per plant were observed in the treatments having the combination of chemical and manual methods (data not presented). Rathi *et al.* (1986) obtained significantly higher yields and effective control of weeds with two hoeings at 15 and 30 DAS. Mechanical or manual weeding sometimes may be delayed either due to continuous rains or the scarcity of labour. Delayed hoeing operations particularly at a much later stage, can be harmful to the crop because of mechanical injury to the gynophores and their displacement from the site of pod development.

If chemical means alone are to be employed for weed control in the initial phase, the herbicides must provide sufficient control to keep the fields weed-free during the critical period of competition (30-45 DAS). Since pre-emergent herbicides dissipate over time, and late emerging and herbicide tolerant weeds have been shown to cause yield reductions (Rathi *et al.*, 1986), integration of chemical and manual methods will provide full season weed control, including herbicide tolerant and late emerging weeds. Furthermore, manual weeding prior to gynophore establishment facilitates entry and development of gynophores of groundnut in the loose soil. Use of herbicides along with weeding not only controlled the weeds effectively but also provided weed-free conditions for longer period of time. Although hand weeding at 30 and 45 DAS during the first year, gave weed control and pod yields comparable to combinations of chemical and manual weeding, an integration of chemical and manual weeding resulted in consistently higher pod yields and effective weed control during both years.

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