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Management of late emerging weeds in irrigated groundnut

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ABSTRACT

Field experiments were conducted during *kharif* (June-July), 2002, and late *rabi* (December-January), 2003 on sandy loam soils of Coimbatore to manage the late emerging weeds in irrigated groundnut. In screening trial, herbicides, metolachlor and fluchloralin were tested at four different levels *viz.,* 0.75, 1.00, 1.25 and 1.50 kg/ha. The experimental fields were dominated by *Setaria verticillata* in grasses, *Cyperus rotundus* in sedges and *Trianthema portulacastrum* in broad-leaved weeds. Higher levels of herbicide dose recorded more weed control efficiency, yield and yield attributes of groundnut irrespective of the herbicides without any adverse effect on the crop. Among the levels, 1.00 kg/ha produced similar results with that of 1.25 or 1.50 kg/ha. Sequential applications of metolachlor as pre emergence at sowing followed by one on 40 DAS preceded with earthing up reduced the weed density, dry matter accumulation and nutrient removal by weeds significantly and comparable with weed free check. Initial reduction on the load of *Rhizobium* gained its original strength at later stages of crop growth.

Key words: Groundnut, Late emerging weeds, Pre-emergence, Metolachlor, Fluchloralin

Groundnut (*Arachis hypogaea*) is one of the major edible oilseed crops extensively cultivated in the world. One of the major constraints in groundnut production is weed menace. Besides competing for nutrients, soil moisture, sunlight, weeds inhibit pegging, pod development in groundnut and interfere with harvest. Weed competition is critical up to 10 weeks after sowing (Rethinam *et al*. 1976, Yaduraju *et al*. 1980), which appear in several flushes during the crop season (Vasisht and Pandey 1999). Because of pulverization of soil and adequate soil moisture, in every hoeing, the weed seeds, which are lying below the soil brought to surface and germinate. The second flush of weeds emerged during late season will seriously affect the pegging and pod development apart from disrupting digging and harvesting operations. The uncontrolled late emerged weeds besides competing with groundnut, infest the land with weed seeds, which makes the land unproductive for subsequent season. Once peg formation has begun, manual or mechanical methods should not be continued as they damage the pegs and roots and reduce crop yields. Thus, herbicides offer the most effective means for the control of weeds that emerged during late season.

Application of post-emergence foliar applied herbicides caused considerable injury to the groundnut crop. Nicosulfuron applied alone or in mixture with 2,4-D five weeks after planting caused greater injury to groundnut crop and reduced pod yield (Littlefield *et al.* 1997). Waiting for the emergence of weeds and attempting to control with post-emergence herbicides may result into depletion of nutrients and other natural resources. Whereas, the soil applied pre-emergence herbicides will be effective in checking the germinating weeds besides, leaving no injury to crop. Application of pre-emergence herbicides at the time of sowing and after earthing up (six weeks after sowing) in sequence may sustain weed free condition for longer period compared to foliar applied post emergence herbicides. Hence, an attempt was made to use the soil applied herbicides to manage late emerging weeds in groundnut.

MATERIALS AND METHODS

Different levels of herbicides metolachlor (2-chloro-N-(2-ethyl-6-methyl phenyl)-N- (2-methoxy-1-methyl ethyl) and fluchloralin (N-(2-chloroethyl)- 2, 6-dinitro benzeneamine -N- propyl - 4 -(trifluoromethyl) each at 0.75, 1.00, 1.25, 1.50 were applied as sand mix at 40 days after sowing (DAS) and assessed for their efficiency in randomized block design in the preliminary study conducted during *kharif* (June-July), 2002. Field was raised with groundnut variety *CO3* (bunch type) and maintained weed free manually upto 40 days. Herbicide treatments were imposed after hoeing and earthing up. Scoring was done to assess the phytotoxicity of the soil applied herbicides on groundnut besides their weed control efficiency.

Based on the results of the preliminary study, main field experiment was conducted during late *rabi* (December-January), 2003 on sandy loam soils of Coimbatore under irrigated groundnut. The experiment was laidout in a randomized block design with eleven treatments replicated thrice. The herbicides

metolachlor or fluchloralin was applied at the rate of 1.00 kg/ha either as single at sowing or 40 days after sowing or in sequence at sowing plus 40 days after sowing. Besides hand weeding twice, weed free and weedy check were maintained for comparison purpose. Calculated quantities of herbicides were mixed with 50 kg dry sand and broadcasted immediately after irrigation. In all the treatments, crop was earthed up at 40 DAS with hand hoe to improve the pegging and pod development. The soil of the experimental field was sandy loam in texture and neutral in reaction. The seeds of groundnut variety *CO3* was planted leaving ten cm between plants and 30 cm apart in rows.

Biometric observations for plants were made by tagging five plants at random in each treatment in the sampling rows. Dry matter accumulation of crop plants were recorded from five separate plants selected at random for each treatment at different growth stages. Pod and haulm yields were worked out by harvesting plants from the net plot area. The other parameters *viz*., number of matured pods per plant, number of pegs per plant, shelling percentage, hundred kernel weight (g), harvest index were also workedout as per the procedure laidout in the literature. Observations on weeds *viz*., weed flora, weed density, weed dry matter, were recorded at 60 days after sowing and at harvest for screening trails and at 20, 40, 60, 80 days after sowing and at harvest for main field experiment. Relative density and relative dry weight of weeds, weed control index, weed control efficiency and weed index were also worked out using standard formula.

RESULTS AND DISCUSSION

Effect of herbicide on weed infestation

Application of herbicides *viz.,* metolachlor and fluchloralin at 40 days after sowing (DAS) irrespective of the dose screened, significantly reduced the weed emergence compared to control plot. Metolachlor recorded fewer weeds compared to fluchloralin at all stages of observations. Higher levels of metolachlor at 1.00 and 1.25 kg/ha significantly reduced the grasses, sedges and broad-leaved weed population compared to its lower levels of 0.75 kg/ha and equally effective as that of 1.5 kg/ha. The second flush of sedges was effectively checked by the application of pre-emergence metolachlor at 40 DAS and that was not altered significantly by the fluchloralin (Table 1).

Nodulation

Application of herbicides at 40 days after sowing did not significantly influence the nodulation of groundnut crop (Table 2). However, number of nodules per plant was decreased when the herbicide dose was increased. Higher number of nodules per plant were observed at lower levels (0.75 and 1.00 kg/ha) of both the herbicides.

Table 1 Effect of herbicides on density (m^2) of weed flora at 60 DAS and at harvest in preliminary screening field trial conducted during *kharif*

Treatments	Grasses (m^2)		Sedges (m^2)		Broad leaved weeds (m^2)		Total weeds (m^2)	
	60 DAS	At Harvest	60 DAS	At Harvest	60 DAS	At Harvest	60 DAS	At Harvest
T_1-Met. 0.75 kg/ha	0.9 (7.3)	1.5 (27.7)	1.7 (45.0)	1.6 (39.4)	1.3 (17.8)	1.5 (30.4)	1.9 (70.1)	2.0 (97.6)
T_2-Met. 1.00 kg/ha	0.9 (5.8)	1.3 (15.7)	1.6 (39.3)	1.5 (32.9)	1.2 (14.5)	1.3 (17.4)	1.8 (59.6)	1.8 (66.0)
T_3-Met. 1.25 kg/ha	0.9 (5.5)	1.2 (14.4)	1.6 (35.5)	1.5 (29.6)	1.2 (14.2)	1.3 (17.0)	1.8 (55.2)	1.8 (61.0)
T_4-Met. 1.50 kg/ha	0.9 (5.4)	1.2 (13.9)	1.5 (31.0)	1.5 (28.5)	1.2 (14.1)	1.3 (16.8)	1.7 (50.5)	1.8 (59.2)
T_5-Flu. 0.75 kg/ha	1.1 (10.2)	1.5 (32.4)	1.7 (51.2)	1.6 (41.7)	1.3 (20.0)	1.7 (46.5)	1.9 (81.4)	2.1 (120.7)
T_6-Flu. 1.00 kg/ha	0.9 (7.0)	1.4 (23.0)	1.7 (47.9)	1.6 (36.7)	1.3 (16.8)	1.5 (29.4)	1.9 (71.6)	2.0 (89.0)
T_7-Flu.1.25 kg/ha	0.9 (6.8)	1.4 (21.4)	1.7 (44.6)	1.6 (34.2)	1.3 (15.2)	1.5 (29.0)	1.8 (66.6)	1.9 (84.6)
T_8-Flu. 1.50 kg/ha	0.9 (6.7)	1.3 (19.9)	1.6 (41.5)	1.5 (33.5)	1.3 (15.1)	1.5 (28.7)	1.8 (63.4)	1.9 (82.0)
T_9-Control	2.2 (153.9)	2.1 (131.4)	1.8 (62.8)	1.7 (50.5)	2.2 (170.4)	2.2 (144.8)	2.6 (386.4)	2.5 (326.6)
LSD (P=0.05)	0.2	0.2	0.2	0.1	0.1	0.2	0.1	0.1

Met-Metolachlor; Flu-Fluchloralin; Number in the parenthesis indicates the original number of weeds; weed number was transformed to log $\sqrt{x+2}$ for statistical analysis, DAS - Days after sowing

Yield and its attributing variables

The growth and yield component of groundnut was significantly improved by the soil-applied herbicides (Table 2). Herbicides applied at 40 DAS effectively checked the late emerging weeds from pegging to maturity and improved the yield and yield contributing variables. Metolachlor at 1.50 kg/ha recorded significantly higher pod yield (2028 kg/ha) compared to 0.75 kg/ha and similar with that of 1.25 and 1.00 kg/ha. The lowest pod yield of 980 kg/ha was recorded in the control plot. Application of fluchloralin at 1.50 kg/ha recorded significantly higher pod yield (2003 kg/ha) compared to 0.75 kg/ha (1460 kg/ha) and on par with 1.25 and 1.0 kg/ha. Between herbicides, metolachlor produced more haulm than fluchloralin. Metolachlor at 1.50 kg/ha produced haulm yield of 2246 kg/ha and it was on par with 1.25 and 1.00 kg/ha.

Based on the above results, it was observed that the application of metolachlor and fluchloralin at 1.00, 1.25 and 1.5 kg/ha performed equally and were better in controlling weeds and improving yield compared to 0.75 kg and control. Between herbicides, metolachlor was superior as compared to fluchloralin for the management of late emerging weeds. Considering the economics and biological reasons, the herbicide dose at 1.00 kg/ha was fixed for both metolachlor and fluchloralin to manage the late emerging weeds in conjunction with cultural practices in the main field experiment.

Total weed population

Sequential applications of metolachlor 1.00 kg/ha as pre-emergence at the time of sowing plus 40 days after sowing as sand mix in combination with hoeing and earthing up significantly reduced the population of grasses, sedges and broad leaved weeds (Table 3). This might be due to the effective control of weeds at critical stages and sustained weed free condition for the rest of the crop growth period (Kalaiselvi *et al.* 1998).

Similarly, sequential application of fluchloralin as pre-emergence at the time of sowing and metolachlor 40 days after sowing or one hand weeding at 20 DAS were also equally effective in reducing the weed population at all stages of crop growth. Application of metolachlor at 40 DAS effectively checked the germination of weed seeds brought to the surface during earthing up enabled the weed free condition throughout the crop period. In addition to grasses and broad-leaved weeds, metolachlor effectively controlled the sedges (Grichar *et al*. 1996).

Sequential applications of pre-emergence herbicide fluchloralin followed by fluchloralin or fluchloralin followed by earthing up or metolachlor followed by fluchloralin or hand weeding (at 20 DAS) followed by fluchloralin effectively controlled the weeds when compared to hand weeding twice. However, the performance was poor when compared to sequential application of metolachlor. This might be due to higher volatilization and photodecomposition nature of fluchloralin (Jordan *et al.*1963, Rajah *et al.* 1984, Durgesha 1994). Application of fluchloralin on the surface of the soil coupled with the prevailing high temperature might have reduced the effect of herbicide. Hence, the herbicide fluchloralin needs incorporation into soil (Sivanarayana and Banumurthy 1994).

In hand weeding at 20 DAS + soil application of herbicide (metolachlor or fluchloralin) at 40 DAS

Table 2 Effect of pre-emergence herbicides applied at 40 DAS on weed control index (WCI) and pod and haulm yield of groundnut in the preliminary screening field trial

Treatments	Weed control index (WCI)	Nodulation (no./plant)	Pod yield (kg/ha)	Haulm yield (kg/ha)
T_1 -Met. 0.75 kg/ha	35.2	19.5	1513	1997
T_2 -Met. 1.00 kg/ha	50.3	15.1	1972	2108
T_3 -Met. 1.25 kg/ha	51.3	12.8	2011	2127
T_4 -Met. 1.50 kg/ha	51.7	10.5	2028	2246
T_5 -Flu. 0.75 kg/ha	32.9	23.6	1460	1876
T_6 -Flu. 1.00 kg/ha	49.2	21.8	1929	2008
T_7 -Flu.1.25 kg/ha	49.7	19.3	1948	2079
T_8 -Flu. 1.50 kg/ha	50.7	17.5	1987	2107
T_9 -Control	0.0	26.4	980	1826
LSD (P=0.05)	-	3.7	387	396

Met. Metolachlor, Flu. Fluchloralin

Table 3 Effect of late season weed management treatments on the total weed population in the main field experiment conducted during *rabi*.

Treatments	Total weed population/m^2				
	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
T_1-M_1+EU_{40}	1.2 (12.0)	1.7 (50.3)	2.2 (148.0)	2.3 (183.0)	2.2 (165.0)
T_2 F_1+EU_{40}	1.7 (44.4)	2.2 (169.8)	2.3 (204.3)	2.4 (219.7)	2.3 (197.0)
T_3-M_1+EU_{40}+M_1	1.1 (10.2)	1.7 (44.2)	1.2 (11.9)	1.4 (24.2)	1.7 (43.0)
T_4 F_1+EU_{40}+F_1	1.7 (48.4)	2.3 (179.2)	1.7 (44.6)	1.9 (82.8)	2.0 (90.7)
T_5 M_1+EU_{40}+F_1	1.2 (13.1)	1.7 (50.9)	1.5 (31.9)	1.9 (72.1)	1.9 (74.3)
T_6 F_1+EU_{40}+M_1	1.7 (54.4)	2.3 (199.7)	1.3 (15.2)	1.5 (26.6)	1.7 (48.4)
T_7-H_{20}+EU_{40}	2.7 (463.3)	2.2 (142.5)	2.5 (299.6)	2.6 (365.9)	2.5 (306.4)
T_8-H_{20}+EU_{40}+M_1	2.7 (479.3)	2.2 (138.0)	1.3 (18.0)	1.5 (29.2)	1.7 (50.9)
T_9-H_{20}+EU_{40}+M_1	2.7 (477.7)	2.2 (152.8)	1.7 (49.0)	2.0 (89.1)	2.0 (90.1)
T_{10}-Weedy check	2.7 (527.0)	2.8 (557.9)	2.8 (584.9)	2.8 (609.6)	2.7 (503.0)
T_{11}-Weed free check	0.8 (4.7)	0.8 (4.4)	0.9 (6.3)	1.0 (8.4)	0.9 (6.4)
LSD (P=0.05)	0.2	0.1	0.1	0.1	0.1

M_1 - Metolachlor 1.00 kg/ha, H_{20} - Hand weeding at 20 DAS, F_1 - Fluchloralin 1.00 kg/ha, EU_{40} - Earthing up at 40 DAS, Figures in the parenthesis indicates the original values; DAS - Days after sowing

recorded equal weed count to that of control plot at 20 DAS. This is because the weeds were allowed to grow freely, undisturbed upto 20 or 40 DAS as that of unweeded check and the count was done just before the operation like manual weeding or earthing up. Hand weeding twice failed to give season long weed control. As it had removed the weeds grown at a point of time, irrigation and inversion of soil during earthing up promoted the germination of weeds and allowed to compete with the crop. Thus, the weed population was higher in hand weeding when compared to herbicide treatments.

Pre-emergence application of metolachlor or fluchloralin immediately after sowing + earthing up at 40 DAS recorded increased weed population at later stages because the pre-emergence herbicides might be effective during the early stages of the crop. Soil disturbance due to earthing up and favourable moisture leads to increased weed count at later stages.

Weed dry matter production

Among the weed control methods, weed free check recorded the lowest weed dry matter production followed by sequential application of metolachlor immediately after sowing + 40 DAS as sand mix application and earthing up (Table 4) due to lower weed density and lesser weeds growth (Gnanamurthy and Balasubramaniyam 1995). The inhibitory effect of protein synthesis by metolachlor was found to be associated with its effectiveness in controlling weed growth (Deal *et al*. 1980). Dry matter production of weeds in hand weeding was higher during the initial stages up to 20 DAS and it was maintained upto harvest of the crop. At 40 DAS, the dry matter production of total weeds in hand weeding twice and hand weeding + pre-emergence application of herbicides were similar as that of sequential application of metolachlor and lower than the fluchloralin application either in sequence or alone. However, hand weeding twice increased the dry matter production of weeds during later stages. It might be due to the favourable environment created for the emergence of fresh weeds at later stages by removal of weeds at 20 DAS. Higher weed DMP in fluchloralin was due to its ineffectiveness to check the season long weed control.

The highest weed dry matter was recorded in weedy check perhaps due the undisturbed weed growth during the entire crop period (Manickam *et al.* 2000). Except in weedy check, the dry matter production of grasses increased during every growth stages of the crop. In weedy check, due to high density and early completion of life cycle led to drying of weeds. However, in other treatments, because of lower density, the grasses grow vigorously and

Table 4. Effect of late season weed management on dry matter production (kg/ha) of total weeds in groundnut main field experiment during *rabi*

Treatments	Total weeds DMP (kg/ha)				
	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
T_1-M_1+EU_{40}	0.93 (6.97)	2.14 (137.83)	2.12 (132.13)	2.41 (253.93)	2.38 (237.47)
T_2-F_1+EU_{40}	1.55 (33.57)	2.36 (230.07)	2.36 (230.57)	2.48 (302.23)	2.44 (273.73)
T_3-M_1+EU_{40}+M_1	0.77 (4.20)	2.11 (129.77)	0.91 (6.10)	1.84 (68.40)	2.07 (116.07)
T_4-F_1+EU_{40}+F_1	1.59 (37.37)	2.38 (240.17)	1.70 (48.20)	2.20 (157.67)	2.34 (220.50)
T_5-M_1+EU_{40}+F_1	0.83 (4.87)	2.16 (146.53)	1.64 (42.13)	2.21 (161.40)	2.32 (209.10)
T_6-F_1+EU_{40}+M_1	1.62 (39.90)	2.39 (248.53)	0.94 (6.70)	1.87 (72.70)	2.08 (120.16)
T_7-H_{20}+EU_{40}	2.13 (132.87)	2.16 (145.73)	2.42 (267.33)	2.65 (450.07)	2.74 (545.28)
T_8-H_{20}+EU_{40}+M_1	2.13 (132.87)	2.18 (149.60)	0.97 (7.43)	1.87 (76.47)	2.11 (130.57)
T_9-H_{20}+EU_{40}+F_1	2.14 (136.57)	2.18 (150.77)	1.72 (52.10)	2.23 (166.43)	2.34 (218.43)
T_{10}-Weedy check	2.23 (167.47)	3.01 (1028.27)	3.14 (1373.73)	3.17 (1493.30)	3.14 (1379.13)
T_{11}-Weed free check	0.38 (0.43)	0.81 (4.98)	0.67 (2.70)	1.18 (13.90)	1.13 (11.41)
LSD (P=0.05)	0.14	0.18	0.13	0.14	0.13

M_1 - Metolachlor 1.00 kg/ha, H_{20} - Hand weeding at 20 DAS, DMP - dry matter production, F_1 - Fluchloralin 1.00 kg/ha, EU40 - Earthing up at 40 DAS, Figures in the parenthesis indicated the original values, DAS - Days after sowing

taller than the crop, effectively utilizing the solar radiation and nutrients thus recorded increased trend of dry matter production during the later stages of the crop (Table 5). The dry matter production of broad-leaved weeds increased during the initial stages of crop growth. Due to desiccation, shedding of leaves and death of weed led to reduction in dry matter production of weeds at the time of harvest (Table 6). During the maturity of crop, the *T. portulacastrum* sheds all leaves and the stems alone remained.

Weed control indices (WCE, WCI and WI)

In the main field experiment, the WCE and WCI were the highest in the weed free check (Table 7). This might be due to the periodical removal and poor regeneration of weeds. The WCE and WCI were highest in the sequential application of metolachlor 1 kg/ha immediately after sowing and after earthing up at 40 DAS was on par with metolachlor soil application at 40 DAS along with either fluchloralin pre-emergence or hoeing 20 DAS. The herbicides rapidly deplete the photosynthate reserves with in the weed system, through the process of induced respiration, inhibition of protein synthesis and photo-synthetic activity lead to control of perennial nut sedge, besides other growth of weeds (Hill *et al.* 1968 and Dixon and Stroller 1982).

The WCE and WCI were lowest in hand weeding twice. Since the weed population under the recommended practice of hand weeding on 20 and 40 DAS was undisturbed until first weeding, might have facilitated the weed flora for its sound establishment. Consequently, the least WCE and WCI were observed with this treatment at initial stages tend to maintain at all the stages of crop growth.

Unweeded control recorded the highest weed index of 67.75 per cent in main field experiment. This indicates the level of competition between the crop and weed for inputs. Higher weed index of hand weeding twice (45.86 per cent) and present recommended practice of fluchloralin as pre-emergence + earthing up 40 DAS (43.17 per cent) indicated higher competition and lower yield in next to unweeded control. Lower weed index was recorded in pre-emergence metolachlor + earthing up + pre-emergence soil application of metolachlor at 40 DAS treatment which showed the least competition from weeds which inturn increased the yield of groundnut. Rafey and Prasad (1995) observed the highest weed index of 50.7 per cent in groundnut due to weeds.

Growth and yield attributes of groundnut

Herbicide treated plots recorded normal plant height except in weedy check, where the height of the primary

Table 5 Effect of late season weed management on dry matter production (kg/ha) of grasses in groundnut main field experiment

Treatments	Grasses DMP (kg/ha)				
	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
T_1-M_1+EU_{40}	0.50 (2.03)	0.99 (7.83)	1.38 (22.33)	1.51 (32.67)	1.59 (39.13)
T_2-F_1+EU_{40}	0.70 (3.30)	1.39 (23.00)	1.60 (38.40)	1.77 (59.87)	1.84 (68.13)
T_3-M_1+EU_{40}+M_1	0.30 (0.00)	0.92 (6.37)	0.36 (0.33)	1.10 (10.67)	1.36 (20.97)
T_4-F_1+EU_{40}+F_1	0.93 (6.73)	1.45 (26.53)	0.71 (3.20)	1.62 (39.50)	1.73 (52.03)
T_5-M_1+EU_{40}+F_1	0.30 (0.00)	0.96 (7.33)	0.67 (2.83)	1.58 (37.93)	1.71 (49.43)
T_6-F_1+EU_{40}+M_1	0.99 (8.00)	1.49 (28.70)	0.42 (0.63)	1.21 (14.43)	1.40 (23.20)
T_7-H_{20}+EU_{40}	1.41 (23.93)	1.56 (34.87)	1.54 (34.17)	1.87 (78.30)	2.28 (190.05)
T_8-H_{20}+EU_{40}+M_1	1.42 (24.03)	1.58 (36.57)	0.49 (1.10)	1.23 (15.60)	1.42 (24.20)
T_9-H_{20}+EU_{40}+F_1	1.48 (28.43)	1.61 (39.03)	0.88 (5.63)	1.63 (40.30)	1.75 (54.23)
T_{10}-Weedy check	1.74 (53.20)	2.56 (361.07)	2.75 (563.27)	2.77 (608.97)	2.76 (584.00)
T_{11}-Weed free check	0.31 (0.07)	0.47 (1.10)	0.38 (0.43)	0.69 (3.37)	0.67 (3.21)
LSD (P=0.05)	0.23	0.13	0.16	0.25	0.15

M_1 - Metolachlor 1.00 kg/ha, H_{20} - Hand weeding at 20 DAS, F_1 - Fluchloralin 1.00 kg/ha, EU_{40} - Earthing up at 40 DAS, Figures in the parenthesis indicated the original values, DAS - Days after sowing

Table 6 Effect of late season weed management on dry matter production (kg/ha) of broad-leaved weeds in groundnut main field experiment conducted during *rabi*

Treatments	Broad-leaved weeds DMP (kg/ha)				
	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
T_1-M_1+EU_{40}	0.69 (2.97)	2.10 (125.57)	1.91 (84.13)	2.29 (193.17)	2.25 (174.80)
T_2-F_1+EU_{40}	1.40 (23.03)	2.29 (195.00)	2.21 (164.83)	2.33 (213.63)	2.26 (180.60)
T_3-M_1+EU_{40}+M_1	0.59 (2.20)	2.07 (118.27)	0.58 (1.83)	1.74 (53.23)	1.95 (90.23)
T_4-F_1+EU_{40}+F_1	1.40 (23.37)	2.30 (201.67)	1.31 (19.27)	1.97 (90.93)	2.16 (142.70)
T_5-M_1+EU_{40}+F_1	0.67 (2.67)	2.11 (133.73)	1.23 (15.50)	2.00 (97.37)	2.13 (134.60)
T_6-F_1+EU_{40}+M_1	1.43 (24.67)	2.32 (208.00)	0.59 (1.93)	1.74 (53.40)	1.95 (91.39)
T_7-H_{20}+EU_{40}	2.01 (101.13)	1.97 (97.00)	2.31 (205.47)	2.53 (337.73)	2.51 (323.17)
T_8-H_{20}+EU_{40}+M_1	2.01 (101.10)	1.99 (99.20)	0.60 (2.03)	1.77 (55.80)	1.99 (100.57)
T_9-H_{20}+EU_{40}+F_1	2.00 (99.87)	1.98 (98.30)	1.33 (20.83)	2.00 (98.60)	2.14 (137.60)
T_{10}-Weedy check	2.03 (104.53)	2.81 (646.50)	2.88 (759.13)	2.91 (818.47)	2.88 (748.67)
T_{11}-Weed free check	0.35 (0.27)	0.66 (2.93)	0.62 (2.13)	1.06 (10.00)	0.97 (7.93)
LSD (P=0.05)	0.13	0.21	0.22	0.14	0.18

M_1 - Metolachlor 1.00 kg/ha, H_{20}-Hand weeding at 20 DAS, F_1 - Fluchloralin 1.00 kg/ha, EU_{40} - Earthing up at 40 DAS, Figures in the parenthesis indicated the original values, DAS - Days after sowing

Table 7 Effect of weed control treatments on weed dry matter production, weed control efficiency (WCE), weed control index (WCI) and weed index (WI) at harvest in main field experiment during *rabi*

Treatments	WCE (%) at harvest	WCI (%) at harvest	WI (%) at harvest
T_1-M_1+EU_{40}	67.2	82.8	40.8
T_2-F_1+EU_{40}	60.8	80.2	43.2
T_3-M_1+EU_{40}+M_1	91.5	91.6	5.3
T_4-F_1+EU_{40}+F_1	82.0	84.1	26.0
T_5-M_1+EU_{40}+F_1	85.2	84.8	25.6
T_6-F_1+EU_{40}+M_1	90.4	91.3	8.9
T_7-H_{20}+EU_{40}	39.1	60.5	45.9
T_8-H_{20}+EU_{40}+M_1	89.9	90.5	11.7
T_9-H_{20}+EU_{40}+F_1	82.1	84.2	27.6
T_{10}-Weedy check	-	-	67.8
T_{11}-Weed free check	98.7	99.2	0.0

M_1-Metolachlor 1.00 kg/ha, H_{20}-Hand weeding at 20 DAS, F_1 - Fluchloralin 1.00 kg/ha, EU_{40}-Earthing up at 40 DAS.

branch was higher (Table 8). Shading of weeds at higher density, the crop, which grown between weeds, produced taller stem. Heavy competition for light and resources by weeds in the unweeded plot checked the production of branches, in turn reduced the production of pods per plant. The growth attributes like LAI and plant dry matter production were also higher in weed free check and were at par with sequential application of metolachlor at the time of sowing and 40 DAS. Weed free condition throughout the peak crop growth period promoted the accumulation of photosynthetic reserves in the herbicides treated plots as well as weed free check.

The yield attributes like matured pods per plant, peg to pod conversion ratio, 100 kernel weight and shelling percentage were higher in weed free check and at par with sequential application of metolachlor. In weedy check, weeds interfered the penetration of pegs and pod development thus reduces the size of the pods. In turn, it led to reduction of 100 kernel weight and shelling percentage in the unweeded control plot.

Pod and haulm yield of groundnut

The highest pod yield of 2423 kg/ha was obtained in weed free check followed by sequential application of metolachlor immediately after sowing and at 40 DAS as sand mixes application (Table 9). The per cent yield increase over control plot was 67.75 and 65.95 % in these treatments, respectively and 45.85 and 42.83% over hand weeding twice, respectively. It confirms that 40.45 % yield increase was due to the effective control of late emerging weeds. The yield reduction due to late emerging weeds was 45.86%.

Apart from the above factors, being a C_3 plant, climatic fluctuations, especially the sunshine hours, temperature gradients, and precipitation had significant influence on the productivity of groundnut (Pallas and Samish 1974). The high productivity of groundnut during the late June-September season might be due to the prevalence of lengthy hours of sunshine and high temperature during flowering and pod development stages.

The perusal of the earlier results revealed that the weed free conditions during the entire crop growth period resulted in appreciable improvement in growth components like plant height, leaf area index and subsequently plant dry matter production. Hence, an accountable increase in haulm yield was obtained with weed free condition.

The considerable increment in haulm yield under sequential application of metolachlor immediately after sowing and at 40 DAS as sand mix application + earthing up confirmed the effectiveness of the treatment. Under weed free conditions, inspite of maximum utilization of available resources, the nutrient up take by groundnut was doubled (Soundararajan *et al.* 1981) and thus increased the vegetative growth of the crop. Furthermore there was an uncontrolled rainfall at 70 DAS, encouraged the vegetative growth of plant during later stages and increased the dry matter accumulation. The haulm yield

Table 8 Effect of late season weed management on growth and yield attributes of groundnut in main field experiment

Treatments	Plant height (cm) at harvest	LAI at harvest (%)	Plant DMP at harvest (kg/ha)	Number of matured pods/plant	Peg to pod conversion (%)	Shelling percentage (%)	100 kernel weight (g)
T_1-M_1+EU_{40}	25.5	2.84	5828	12.7	51.84	70.41	32.48
T_2-F_1+EU_{40}	25.1	2.82	5473	12.3	46.44	69.94	31.63
T_3-M_1+EU_{40}+M_1	29.9	3.74	7507	16.9	50.34	71.44	36.24
T_4-F_1+EU_{40}+F_1	27.9	3.12	6583	15.0	53.38	71.09	33.22
T_5-M_1+EU_{40}+F_1	28.3	3.25	6892	15.1	59.57	71.38	34.99
T_6-F_1+EU_{40}+M_1	29.7	3.71	7443	16.5	48.94	72.23	35.59
T_7-H_{20}+EU_{40}	35.1	2.65	5172	11.0	47.39	69.89	31.49
T_8-H_{20}+EU_{40}+M_1	29.4	3.70	7173	16.4	50.99	72.15	35.45
T_9-H_{20}+EU_{40}+F_1	27.3	2.90	6118	14.8	48.23	70.87	33.13
T_{10}-Weedy check	38.9	1.32	4400	3.1	55.57	64.33	30.46
T_{11}-Weed free check	31.5	4.12	7800	18.4	53.58	72.20	36.30
LSD (P=0.05)	4.8	0.28	697	1.0	8.85	5.03	1.91

M_1- Metolachlor 1.00 kg/ha, H_{20}- Hand weeding at 20 DAS, F_1- Fluchloralin 1.00 kg/ha, EU_{40}- Earthing up at 40 DAS, LAI - Leaf area index

was lowest in weedy check followed by hand weeding twice. In these treatments, crops compete with weeds and both crop and weeds shared the resources. This caused deficiency of nutrients and reduced the dry matter accumulation of crop.

Based on the results, sequential application of metolachlor at the time of sowing and 40 DAS as sand mix prevented the contamination of field with weed seeds besides increasing the pod yield of groundnut grown under irrigated condition.

Table 9 Effect of late season weed management on pod and haulm yield of groundnut in main field experiment

Treatments	Dry pod yield (kg/ha)	Haulm yield (kg/ha)
T_1-M_1+EU_{40}	1434	2199
T_2-F_1+EU_{40}	1377	2112
T_3-M_1+EU_{40}+M_1	2295	2527
T_4-F_1+EU_{40}+F_1	1793	2312
T_5-M_1+EU_{40}+F_1	1803	2389
T_6-F_1+EU_{40}+M_1	2208	2502
T_7-H_{20}+EU_{40}	1312	1971
T_8-H_{20}+EU_{40}+M_1	2140	2471
T_9-H_{20}+EU_{40}+F_1	1754	2278
T_{10}-Weedy check	781	1801
T_{11}-Weed free check	2423	2600
LSD (P=0.05)	209	143

M_1- Metolachlor 1.00 kg/ha, H_{20} - Hand weeding at 20 DAS, F_1- Fluchloralin 1.00 kg/ha, EU_{40} - Earthing up at 40 DAS

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