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# INFLUENCE OF INTEGRATED USE OF HERBICIDE AND ALLELOPATHIC AQUEOUS EXTRACTS ON WEEDS AND GROUNDNUT CROP PERFORMANCE

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## ABSTRACT

Allelopathicaqueous extracts can be used in integration with herbicides for controlling weeds in field crops. Effect of allelopathic water extracts and their mixtures with haloxyfop 10.8 EC was investigated to control weeds in groundnut and subsequent effects on crop yield through field experiments executed under rainfed conditions during 2009-2011. Treatments included weedy check, hand weeding, haloxyfop 10.8 EC @ 108 g a.i. ha$^{-1}$, barley water extract, brassica water extract, barley+brassica water extract and its combinations with 25, 50 and 75% rates of haloxyfop 10.8 EC arranged in randomized complete block design replicated four times. Results demonstrated that mixture of allelopathic extracts with lower doses of haloxyfopreduced density and dry weights of weed species by 9-58% and 10-52%, respectively. Haloxyfop 10.8 EC @ 108 g a.i. ha$^{-1}$ reduced these parameters upto59% and 54%. Hand weeding decreased density and dry weight of weed species by 50-88%. Statistically similar yields were obtained from allelopathic water extracts combined with reduced rates of herbicide and its full dose. The maximum pods yield was recorded from hand weedingbut the maximum net benefits were achieved from barley and brassica water extracts mixed with 75% rates of haloxyfop 10.8 EC. Crop yield and net benefit showed inverse relationship with weed density and total dry biomass of weeds during both the years. Barley and brassicaaqueous extracts with lower rates of haloxyfop 10.8 EC may be used to manage weeds economically in groundnut crop under rainfed conditions.

**Keywords**: weeds, water extracts, allelopathy, groundnut, barley, brassica.

## INTRODUCTION

Groundnut (*Arachishypogaea* L.) is a major oilseed crop of Pothwarregion (comprising of Rawalpindi, Attock, Chakwal and Jhelum) Punjab, Pakistan. It was sown over an area of 81700 hectares with total production of 81300 tons. Its average yield in Pakistan (991 kg ha$^{-1}$) is lower than that of the world (Anonymous, 2013). There are many factors contributing towards yield reduction of this crop but weeds infestation is a major one. It can reduce groundnut yields upto 70% (Drennan and Jennings, 2006). Weeds in the crop are generally managed manually and with application of herbicides. Manual method although effective to manage weeds yet costly and labour intensive. Due to rapid industrialization, availability of agricultural labour is decreasing day by day. Chemical method has its own limitations like weather dependence and resistance development in weed species through continuous use of chemical herbicides. It also poses environmental and health hazards (Richard *et al*., 2005). There arises a need to develop environment friendly approaches to manage weeds economically without affecting quality and health of the produce. Allelopathy is a natural and environmentallysoundstrategyhavingpotential to manage weeds. It deals with the direct influence of allelochemicals produced by one living plant on the growth and development of neighboring plant species (Minorsky, 2002). These chemicals are discharged in the environment through dissolution of toxins of decomposed and fresh litter in water (Narwal, 2004).

Brassica species contained higher quantity of glucosinolates to interfere growth of other species (Branca *et al.*, 2002). These are hydrolyzed to iso-thiocyanates possessing suppressive effects on weeds (Warton *et al*., 2001). Barley allelopathic extracts and its residues incorporated in soil demonstrated inhibitory effects on selected weed species. It produced phytotoxic substances which suppressed weeds dry matter accumulation (Ben-Hammouda *et al.*, 2001). Barley water extracts producedcaffeic acid, hydrocinnamic acid, ferulic acid, *m*-coumaric acid, *p*-coumaric acid and coumarins (Chon and Kim, 2004), these are considered having inhibitory effects on other species.

Allelopathic crop water extracts helpedto suppress the growth of weeds. Ashraf and Naeem (2005) concluded that combination of sorghum and sunflower water extracts suppressed weeds density, fresh and dry weight of weeds stronger than their individual crop water extracts. Furthermore, allelochemicals and allelopathic extracts can be used along with reduced doses of herbicides to get better weed control (Jamil *et al.*, 2005).

Generally, weeds are controlled manually in groundnut crop in Pothwar region. Some pre emergence herbicides are also being employed but these havecertain limitations. Herbicides application required proper moisture for their effectiveness. Moisture availability is a limiting factor in rainfed agriculture. Keeping it in mind, post emergence herbicides along with allelopathic extracts was examined to manage weeds in this cash crop of the area. Hence, study aimed the reduction of herbicide usage through integration with allelopathic crop water extracts to keep weeds under threshold level. The findings of the study may help the farmers to use allelopathic crops to manage weeds economically with environment friendly approach.

## MATERIALS AND METHODS

Effect of allelopathic water extracts and their mixtures with haloxyfop 10.8 EC was investigated to control weeds in groundnut and subsequent effects on crop yield through field experiments executed at *PMAS*-Arid Agriculture University, Research Farm, Chakwal Road, Rawalpindi during 2009 and 2011. The experiments were conducted on loamy soil having pH 7.6, 0.62% organic matter, 3.7 mg/kg available P and 60 mg/kg available K.

Barley (*Hordeumvulgare* L. cv. Stirling) and brassica (*Brassica campesrtis* L. cv. Chakwal Sarson) herbage were collected from University Farm at their maturity. It was dried under shade to avoid loss of allelochemicals. Dried crop straw was chopped into small pieces and stored to make fresh crop water extract. The chopped herbage of each crop was soaked in tap water in a ratio of 1:10 (w/v) for 24 hours at room temperature. The extract was filtered with the help of sieves and filtrate was boiled to reduce the volume upto 20 times. These concentrated water extracts were used in respective treatments of the study.

Seed bed was prepared employing three ploughings followed by two plankings in a winter fallow field. Groundnut (*Arachishypogaea* L. cv. BARI 2000) was sown on April 24, 2009 for first year and the experiment was repeated during 2010 but failed to germinate due to moisture shortage so it was conducted again during next season and sowing was carried out on April 14, 2011. Sowing was performed with tractor drawn cultivator attached with pores using kernels @ 100 kgha$^{-1}$ at row spacing of 45cm. Planting distance was maintained at 15 cm by uprooting extra plants. Fertilizers were applied at recommended rates (25, 75, 50 NPK kg ha$^{-1}$) uniformly in all plots at final seed bed preparation. Herbicide and its combinations with crop extracts were sprayed at 30 days after sowing (DAS) with Knapsack sprayer after calibration using water @ 375 L ha$^{-1}$. Allelopathic crop extracts alone and their mutual mixtures were sprayed at 30 and 50 DAS.The experiment was performed in randomized complete block design with four replications. Treatments included weedy check, hand weeding, Haloxyfop 10.8 EC @ 108 g a.i. ha$^{-1}$ spray at 30 DAS, barley water extract @ 20 L ha$^{-1}$spray at 30 and 50 DAS, brassica water extract @ 20 L ha$^{-1}$ spray at 30 and 50 DAS, barley + brassica water extract @ 10 + 10 L ha$^{-1}$ spray at 30 and 50 DAS, barley + brassica water extract @ 10 + 10 L ha$^{-1}$ + Haloxyfop 10.8 EC @ 27 g a.i. ha$^{-1}$ spray at 30 DAS, barley + brassica water extract @ 10 + 10 L ha$^{-1}$ + Haloxyfop 10.8 EC @ 54 g a.i. ha$^{-1}$ spray at 30 DAS and barley + brassica water extract @ 10 + 10 L ha$^{-1}$ + Haloxyfop 10.8 EC @ 81 g a.i. ha$^{-1}$ spray at 30 DAS.

Weather data collected from the nearest meteorological station for both crop seasons is given in table 1. Data on weeds density and dry weight of individual weed species per unit area were recorded at 65 DAS. Groundnut pods yield were recorded at crop harvesting (22-11-2009 and 22-11-2011). The data were subjected to analysis of variance technique and the means obtained were compared by least significant difference test (LSD) at five percent level of significance (Montgomery, 2001). Net benefits were calculated based on market prices of inputs and the produce.

## RESULTS AND DISCUSSION

Weeds speciespresentat the experimental site during both years of experiments were *Desmostachyabipinnata* (L.) Stapf (Big cord grass), *Cynodondactylon* (L) Pers (Bermuda grass), *Brachiariareptans* (Running grass), *Tribulusterristris* L. (Puncture vine), *Cyperusrotundus* L. (purple nut sedge) and *Digeraarvensis* Forsk. (False amaranth).However, the two weed species [*Cyperusrotundus* L. (purple nut sedge) and *Digeraarvensis* Forsk. (False amaranth)] were only few in numbers.

### Density and Dry Weight (g m$^{-2}$) of Weed Species

**Big cord grass (*Desmostachyabipinnata*. (L.) Stapf):** All treatments except hand weeding showed statistically similar density of big cord grass at 65 DAS during 2009 and 2011 (Table 2,3). Relatively lower densities of the weed were recorded during 2011. It may be due to soil disturbance with ploughing which destroyed its rhizomes.Crop was sown during 2010 after proper land preparation which could not germinate due to lack of moisture. Weeds present in the field were uprooted with ploughing and dried with weather effects. It may have affected the emergence of this particularweed during 2011 so less density of the weed was observed. Bilalis *et al.* (2001) found higher density of perennial weeds in no till fields because of undisturbed root system. Similarly, Sher *et al*. (2011) reported decline of viable rhizomes with cultivation.

Density of *Desmostachya* varied between 0.75 to 8.25 m$^{-2}$ during both years. Hand weeding decreased density of big cord grass by 77 to 88%. Zubair *et al.* (2009) concluded that weeds can be controlled effectively in field crops through hand weeding.Crop extracts and herbicide could not reduce the density of big cord grass. It may be due to deep root system and perennial nature of weed with rhizomes resistant to common herbicides.

Most of the treatments showed statistically similar dry weight of big cord grass compared with weedy check at 65 DAS during both seasons. The maximum dry weight of big cord grass was recorded from weedy check, while the maximum reduction (75 to 88%) of dry weight observed from hand weeding during both years (Table 4, 5). Relatively higher dry weight was determined during 2009 because of its higher density compared with 2011.

During first season, dry weight of big cord grass varied from 4.26-35.53 g $m^{-2}$. Weed control achieved through different treatments ranged from 5.63 to 88%. The highest weed control (88%) was observed from hand weeding followed by mixture of barley and brassica water extracts with 50-75% rates of Haloxyfop 10.8 EC where dry weight ranged from 2.38 to 9.48 g $m^{-2}$ during second season. Hand weeding reduced dry weight (75%) significantly compared with weedy check. Reduction in dry weight of big cord grass achieved from other treatments ranged from 5 to 17% over control. Most of the treatments were at par with weedy check.

Hand weeding proved effective treatment for reducing biomass of big cord grass during study. Herbicide (Haloxyfop) could not decline its weight significantly because of its tolerance to the chemical. It had intensive system of underground rhizomes and could not be managed with haloxyfop (Shad and Siddiqui, 1996). Zubair *et al*. (2009) found hand weeding as effective control measure while Qureshi (2004) concluded that perennial weeds can be managed by cultural practices.

**Bermuda grass (*Cynodondactylon* (L.) Pers):** Half of the treatments decreased density of bermuda grass at 65 DAS during both seasons. The maximum reduction in its density was observed from hand weeding followed by Haloxyfop 10.8 EC @ 108 g a.i. $ha^{-1}$, mixture of barley and brassica water extracts (WE) with Haloxyfop 10.8 EC @ 54 and 81 g a.i. $ha^{-1}$ (Table 2, 3). Hand weeding decreased its density by 80 and 67% during 2009 and 2011, respectively. Allelopathic crop extracts decreased it by 5 to 17% during both years.Relatively higher densities of bermuda grass were recorded during 2009 as compared to 2011. The lower densities during 2011 may be ascribed to weeds mortality due to tillage operations during 2010 and thereafter dry conditions, hence reduced the viable stolons- a mean to continue next generation. Bilalis *et al.* (2001) found tillage practices as a strategy to decrease density of perennial weeds. Dalley *et al.* (2013) reported lower bermuda grass infestation with conventional tillage compared with reduced and no tillage.

Herbicide alone decreased density of bermuda grass by 40-50% and its combinations with allelopathic extracts depressed it by 15 to 58% during both years. Hand weeding was found an effective method for controlling *Cynodondactylon* followed by chemical control with herbicides. Raju, (2010) and Riaz *et al*. (2007) demonstrated mechanical and chemical methods combined with hand weeding as effective method in reducing density of bermuda grass.

Most of the treatments significantly depressed dry weight of bermuda grass during both seasons. Dry weight of *Cynodondactylon* ranged from 0.92 to 4.84 g $m^{-2}$ among all treatments. The highest dry weight was recorded from weedy check. Maximum decrease in dry weight was achieved with hand weeding which reduced it by 68 to 71% (Table 4, 5). During first season, dry weight ranged from 1.39 to 4.84 g $m^{-2}$. Hand weeding decreased dry weight to the maximum extent (71%) followed by Haloxyfop 10.8 EC @ 108 g a.i. $ha^{-1}$ (52%), barley and brassica WE combined with 75% rates of Haloxyfop 10.8 EC (48%) and 50% rates of Haloxyfop 10.8 EC (38%). Allelopathic extracts (barley and brassica WE and their mutual combination) gave statistically similar control of dry biomass of bermuda grass. Herbicide applied at its recommended dose (108 g a.i. $ha^{-1}$) was at par with its 50-75% rates combined with barley and brassica WE in suppressing dry weight of bermuda grass.

The maximum reduction in dry weight of *Cynodondactylon* during 2011 was also obtained from hand weeding (68%) at par with full dose of Haloxyfop 10.8 EC and mixture of allelopathic WE with its 75% rates. Raju (2010) observed control of bermuda grass with hand weeding more effective than chemical methods. Allelopathic extracts combined with lower rates of herbicide decreased dry weight of *Cynodondactylon* upto 52.5% which was at par with recommended dose of the chemical. Haq *et al*. (2010) concluded that bermuda grass biomass can be decreased by using allelopathic extracts. Our results showed herbicide application depressed dry weight of the weed. Similarly, Masum *et al*. (2011) observed reduced biomass of bermuda grass with herbicides usage in different crops.

**Running grass (*Brachiariareptans*):** Most of the treatments decreased density of running grass significantly during both years. Its density ranged from 7 to 45.5 $m^{-2}$during 2009 and 2011 (Table 2, 3). Hand weeding reduced density of running grass by 51 to 53% during 2009 and 2011, respectively.During first year the maximum reduction in density of running grass was observed from recommended rate of herbicide (59%) followed by 75% dose of herbicide mixed with allelopathic water extracts (56%) and hand weeding (51%).During 2011, the maximum suppression in its density was recorded from hand weeding (53%) followed by 75% rate of herbicide mixed with barley and brassica WE (37%) and recommended rates of haloxyfop 10.8 EC (35%). Higher densities of running grass were counted during 2011 as compared to 2009. Higher densities of perennial weeds were recorded during first season but the space was filled with annual weeds during second season. Bilalis *et al.* (2001) reported higher densities of annual weeds under conventional tillage systems.

All weed control treatments except brassica WE reduced dry weight of running grass during both seasons. Its dry weight varied between 1.81 to 10.20 g $m^{-2}$ (Table 4, 5). Higher dry weight of this weed was observed during 2011 probably due to its more numbers per unit area compared with 2009. Hand weeding gave the maximum reduction of dry weight equivalent to 52 to 54% during 2009 and 2011, respectively.

Maximum decrease of dry weight was recorded from hand weeding followed by recommended rates of Haloxyfop 10.8 EC (48%), barley and brassica WE mixed with 75% rates of Haloxyfop (47.8%) and 50% rates of Haloxyfop combined with allelopathic WE (38%) during 2009. Similar trend of reduction in dry biomass of the weed was observed during 2011. Sharara *et al*. (2005) also reported higher weed control with hand weeding. Recommended dose of herbicide was statistically at par with 50-75% rates of herbicide integrated with allelopathic WE in decreasing dry weight of the weed (Farooq *et al.,* 2011). Hence, results of present experiment are consistent to above findings. Present experiments were conducted under rainfed conditions whereas reported ones were under normal irrigated areas where there is no limitation of moisture availability for spraying herbicide.

**Puncture vine (*Tribulusterristris* L.):** All treatments except hand weeding showed statistically similar impact on the density of *Tribulusterristris* at 65 DAS during both years (Table 2, 3). Higher densities of puncture vine were recorded during second year which may be due to increased seed bank. Hand weeding suppressed its density by 50-62% during 2009 and 2011, respectively. Ali *et al*. (2011) achieved reduction of kharif (summer) weeds density with hand weeding. Other treatments could not control population of puncture vine effectively during study. Haloxyfop 10.8 EC was a grass killer herbicide so this weed was out of its spectrum and allelopathic crop water extracts were also unable to kill puncture vine.

Few treatments depressed dry weight of puncture vine significantly at 65 DAS during both the seasons. Higher dry weight was found during 2011 (Table 4, 5) in all treatments compared with 2009 because of higher weeds infestation during second year. During 2009, most of the treatments were statistically similar with weedy check. Hand weeding reduced its dry weight by 60%. The lowest reduction of dry weight was achieved from herbicide application (0.8%). Other weed control treatments decreased dry weight of *Tribulusterristris* by 5.63 to 15.55%. During 2011, all treatments except hand weeding produced similar dry weight of puncture vine. Hand weeding suppressed dry weight up to 61% while all other treatments declined it upto 16%. Haloxyfop was a recommended herbicide for grassy weeds (Harrington and Gregory, 2009). Puncture vine was not inhibited by the herbicide due to its dicot nature. Hand weeding was found a successful method to control weeds (Zubair *et al.,* 2009).

**Pods Yield (kg $ha^{-1}$) and Net Benefits (Rs./ha):** Data presented in table 6 revealed that weed control treatments enhanced pods yield over weedy check during both years. During 2009, hand weeding out yielded (1527 kg $ha^{-1}$) rest of the treatments followed by allelopathic WE mixed with 75% dose of Haloxyfop10.8 EC (1409 kg $ha^{-1}$), 50% dose of Haloxyfop10.8 EC combined with allelopathic WE (1378 kg $ha^{-1}$) and full dose of Haloxyfop 10.8 EC (1373 kg $ha^{-1}$). Allelopathic extracts alone improved yields but lower than herbicide and its mixtures with these extracts. During second season, hand weeding again produced the highest pod yields (1401 kg $ha^{-1}$) followed by allelopathic WE integrated with 75 and 50% rates of Haloxyfop 10.8 EC. The lowest pods yield was observed from weedy check due to higher weeds density and biomass. Better yields from weed control treatments were achieved due to weeds suppression, more pods/ plant and kernels/ pod compared with check. The findings are in coincidence with those of Khan *et al*. (2011) who found higher seed yields of mungbean with herbicide application and hand weeding under rainfed conditions. Higher pod yields were obtained from weed free plots followed by usage of metolachlor (pre-em) compared with weedy check (Kanagum and Chinnamuthu, 2009). Similarly, Chandolia *et al*. (2010) obtained higher yields with application of herbicides, hand weeding and their integration as compared with weedy control.

Intime control or keeping weeds under threshold level encourages rigorous plant growth and ultimately better yield and net benefits. An inverse and significant relationship of pod yield with total weedsdensity and total weeds dry biomass (Coefficients of determination equivalent to 0.9111, 0.7901; 0.652 and 0.7155during 2009 and 2011, respectively) (Fig. 1, 2, 3 and 4) is supportive to above analogy.

Although hand weeding was effective treatment in reducing weeds density and biomass and it also produced the highest pod yields yet it was not economically viable strategy due to less net benefits (Table 6). The highest (Rs. 73663 and 71443 $ha^{-1}$) net benefits were obtained from allelopathic crop WE mixed with 75% rates of Haloxyfop 10.8 EC followed by combination of WE with 50% rates of Haloxyfop 10.8 EC (Rs. 72496 and 71246 $ha^{-1}$). An inverse relationship between total weeds dynamics (density and biomass) and net benefits was recorded during both years (Fig. 1, 2, 3 and 4).

Barley and brassica WE @ 10+10 L ha$^{-1}$ combined with 50-75% rates of Haloxyfop 10.8 EC may be used to suppress summer weeds in groundnut crop thereby increasing its economic yields under rainfed conditions of Pothwar region. Combination of other allelopathic crop WE and available herbicides may be studied further to control resistant and hard weeds in the area.

**Table 1. Rainfall and mean temperatures during 2009 and 2011**

| Months | 2009 | | | 2011 | | |
|---|---|---|---|---|---|---|
| | Rainfall (mm) | Mean minimum temperature ($^0$C) | Mean maximum temperature ($^0$C) | Rainfall (mm) | Mean minimum temperature ($^0$C) | Mean maximum temperature ($^0$C) |
| January | 19.70 | 2.01 | 18.21 | 4.00 | -0.49 | 16.11 |
| February | 39 | 3.96 | 19.99 | 87.70 | 6.56 | 16.11 |
| March | 39.8 | 7.98 | 25.28 | 23.00 | 12.86 | 24.75 |
| April | 84.60 | 12.23 | 29.70 | 44.20 | 13.32 | 28.03 |
| May | 39.90 | 17.90 | 37.24 | 35.80 | 20.95 | 37.81 |
| June | 5.60 | 21.12 | 39.39 | 51.50 | 24.65 | 38.04 |
| July | 189.35 | 22.52 | 36.51 | 130.10 | 23.87 | 33.43 |
| August | 75.70 | 23.02 | 35.82 | 237.95 | 24.07 | 31.67 |
| September | 40.00 | 19.90 | 34.90 | 40.20 | 21.64 | 31.04 |
| October | 4.00 | 12.78 | 32.98 | 16.50 | 14.75 | 29.95 |
| November | 7.09 | 7.13 | 23.00 | 12.70 | 9.11 | 24.89 |
| December | 0.00 | 6.86 | 25.54 | 0.00 | 2.20 | 19.31 |

**Table 2. Effect of weed control treatments on weeds density at 65 DAS during 2009**

| Treatments | Weeds density (No. m$^{-2}$) | | | |
|---|---|---|---|---|
| | ***Desmostachyabipinnata*** | ***Cynodondactylon*** | ***Brachiariareptans*** | ***Tribulusterristris*** |
| Weedy check | 8.25 a | 5.00 a | 17 a | 2.0 a |
| Hand Weeding | 1.00 b (87.88) | 1.00 d (80) | 8.25 cd (51.47) | 1 b (50.00) |
| Haloxyfop 10.8 EC@ 108 g a.i. ha$^{-1}$ | 8.00 a (3.03) | 3.00 c (40) | 7 d (58.82) | 1.75 ab (12.50) |
| Barley water extract (BWE) @ 20 L ha$^{-1}$ | 8.25 a (-) | 4.50 ab (10) | 16.75 a (1.47) | 2.25 a (12.50) |
| Brassica water extract (BrasWE) @ 20 L ha$^{-1}$ | 7.75 a (6.06) | 4.75 a (5) | 17.5 a (2.94) | 2.0 a (-) |
| BWE + BrasWE @ 10+10 L ha$^{-1}$ | 7.75 a (6.06) | 4.50 ab (10) | 17.25 a (1.47) | 1.75 ab (12.50) |
| BWE + BrasWE @ 10+10 L ha$^{-1}$ + Haloxyfop 10.8 EC @ 27 g a.i. ha$^{-1}$ | 7.50 a (9.09) | 4.25 ab (15) | 10.5 b (38.24) | 2.25 a (12.50) |
| BWE + BrasWE @ 10+10 L ha$^{-1}$ + Haloxyfop 10.8 EC @ 54 g a.i. ha$^{-1}$ | 7.50 a (9.09) | 3.75 bc (25) | 9.75 bc (42.65) | 1.75 ab (12.50) |
| BWE + BrasWE @ 10+10 L ha$^{-1}$ + Haloxyfop 10.8 EC @ 81 g a.i. ha$^{-1}$ | 7.25 a (12.12) | 3.25 c (35) | 7.5 d (55.88) | 1.5 ab (25.00) |
| LSD at α 5% | 1.07 | 0.97 | 1.57 | 0.96 |

Means sharing same letters are non significant at α = 5%.
Parenthetic figures represent % decrease over weedy check.

**Table 3. Effect of weed control treatments on weeds density at 65 DAS during 2011**

| Treatments | Weeds density (No. $m^{-2}$) | | | |
|---|---|---|---|---|
| | ***Desmostachyabipinnata*** | ***Cynodondactylon*** | ***Brachiariareptans*** | ***Tribulusterristris*** |
| Weedy check | 3.0 a | 3.0 a | 45.5 a | 3.25 a |
| Hand Weeding | 0.75 b (76.92) | 1 d (66.67) | 21.25 f (53.30) | 1.25 b (61.54) |
| Haloxyfop 10.8 EC@ 108 g a.i. $ha^{-1}$ | 2.75 a (15.38) | 1.5 cd (50.0) | 29.75 de (34.62) | 3.0 a (7.69) |
| Barley water extract (BWE) @ 20 L $ha^{-1}$ | 2.5 a (23.08) | 2.75 ab (8.33) | 40.5 bc (10.99) | 3.0 a (7.69) |
| Brassica water extract (BrasWE) @ 20 L $ha^{-1}$ | 2.75 a (15.38) | 2.75 ab (8.33) | 42.25 ab (7.14) | 3.25 a (-) |
| BWE + BrasWE @ 10+10 L $ha^{-1}$ | 2.5 a (23.08) | 2.5 abc (16.67) | 39.5 bc (13.19) | 3.5 a (7.69) |
| BWE + BrasWE @ 10+10 L $ha^{-1}$ + Haloxyfop 10.8 EC @ 27 g a.i. $ha^{-1}$ | 2.5 a (23.08) | 2 abcd (33.33) | 37.5 c (17.58) | 3.0 a (7.69) |
| BWE + BrasWE @ 10+10 L $ha^{-1}$ + Haloxyfop 10.8 EC @ 54 g a.i. $ha^{-1}$ | 2.75 a (15.38) | 1.75 bcd (41.67) | 33.5 d (26.37) | 3.25 a (-) |
| BWE + BrasWE @ 10+10 L $ha^{-1}$ + Haloxyfop 10.8 EC @ 81 g a.i. $ha^{-1}$ | 2.5 a (23.08) | 1.25 d (58.33) | 28.75 e (36.81) | 3.0 a (7.69) |
| LSD at α 5% | 0.98 | 1.22 | 3.90 | 1.06 |

Means sharing same letters are non significant at α = 5%. Parenthetic figures represent % decrease over weedy check.

**Table 4. Effect of weed control treatments on dry weight of weeds at 65 DAS during 2009**

| Treatments | Weeds dry weight (g $m^{-2}$) | | | |
|---|---|---|---|---|
| | ***Desmostachyabipinnata*** | ***Cynodondactylon*** | ***Brachiariareptans*** | ***Tribulusterristris*** |
| Weedy check | 35.53 a | 4.84 a | 3.76 a | 3.73 a |
| Hand Weeding | 4.26 c (88.01) | 1.39 f (71.25) | 1.81 f (51.86) | 1.49 c (60.05) |
| Haloxyfop 10.8 EC@ 108 g a.i. $ha^{-1}$ | 33.53 ab (5.63) | 2.33 e (51.86) | 1.95 ef (48.09) | 3.7 ab (0.8) |
| Barley water extract (BWE) @ 20 L $ha^{-1}$ | 32.79 ab (7.71) | 4.07 bc (15.91) | 3.26 bc (13.30) | 3.36 ab (9.92) |
| Brassica water extract (BrasWE) @ 20 L $ha^{-1}$ | 33.27 ab (6.36) | 4.33 ab (10.54) | 3.60 ab (4.26) | 3.52 ab (5.63) |
| BWE + BrasWE @ 10+10 L $ha^{-1}$ | 32.05 ab (9.79) | 3.96 bc (18.18) | 3.15 c (16.22) | 3.26 ab (12.60) |
| BWE + BrasWE @ 10+10 L $ha^{-1}$ + Haloxyfop 10.8 EC @ 27 g a.i. $ha^{-1}$ | 31.94 ab (10.10) | 3.44 cd (28.93) | 2.59 d (31.04) | 3.23 ab (13.40) |
| BWE + BrasWE @ 10+10 L $ha^{-1}$ + Haloxyfop 10.8 EC @ 54 g a.i. $ha^{-1}$ | 31.55 b (11.20) | 2.98 de (38.43) | 2.34 de (37.75) | 3.16 b (15.28) |
| BWE + BrasWE @ 10+10 L $ha^{-1}$ + Haloxyfop 10.8 EC @ 81 g a.i. $ha^{-1}$ | 31.24 b (12.07) | 2.52 e (47.93) | 1.96 ef (47.82) | 3.15 b (15.55) |
| LSD at α 5% | 3.85 | 0.73 | 0.33 | 0.57 |

Means sharing same letters are non significant at α = 5%. Parenthetic figures represent % decrease over weedy check.

**Table 5. Effect of weed control treatments on weeds dry weight at 65 DAS during 2011**

| Treatments | Weeds dry weight (g $m^{-2}$) | | | |
|---|---|---|---|---|
| | ***Desmostachyabipinnata*** | ***Cynodondactylon*** | ***Brachiariareptans*** | ***Tribulusterristris*** |
| Weedy check | 9.48 a | 2.87 a | 10.20 a | 5.25 a |
| Hand Weeding | 2.38 e (74.85) | 0.92 f (67.99) | 4.70 g (53.95) | 2.06 d (60.73) |
| Haloxyfop 10.8 EC@ 108 g a.i. $ha^{-1}$ | 9.00 ab (5.08) | 1.31 ef (54.52) | 5.65 ef (44.62) | 5.14 ab (2) |
| Barley water extract (BWE) @ 20 L $ha^{-1}$ | 8.50 abcd (10.31) | 2.49 ab (13.40) | 8.9 bc (12.68) | 4.71 bc (10.21) |
| Brassica water extract (BrasWE) @ 20 L $ha^{-1}$ | 8.97 abc (5.33) | 2.59 ab (9.83) | 9.69 ab (5.05) | 4.88 abc (7.08) |
| BWE + BrasWE @ 10+10 L $ha^{-1}$ | 8.26 bcd (12.87) | 2.32 bc (19.23) | 8.67 c (15.04) | 4.53 c (13.64) |
| BWE + BrasWE @ 10+10 L $ha^{-1}$ + Haloxyfop 10.8 EC @ 27 g a.i. $ha^{-1}$ | 8.01 bcd (15.51) | 1.98 cd (30.88) | 7.60 d (25.46) | 4.50 c (14.35) |
| BWE + BrasWE @ 10+10 L $ha^{-1}$ + Haloxyfop 10.8 EC @ 54 g a.i. $ha^{-1}$ | 7.89 d (16.79) | 1.75 de (39.03) | 6.47 e (36.58) | 4.45 c (15.20) |
| BWE + BrasWE @ 10+10 L $ha^{-1}$ + Haloxyfop 10.8 EC @ 81 g a.i. $ha^{-1}$ | 7.95 cd (16.16) | 1.36 ef (52.52) | 5.19 fg (49.16) | 4.40 c (16.21) |
| LSD at α 5% | 1.03 | 0.46 | 0.88 | 0.50 |

Means sharing same letters are non significant at α = 5%. Parenthetic figures represent % decrease over weedy check.

**Table 6. Effect of weed control treatments on pods yield and net benefits of groundnut**

| Treatments | Pods yield (kg $ha^{-1}$) | | Net benefits (Rs. $ha^{-1}$) | |
|---|---|---|---|---|
| | **2009** | **2011** | **2009** | **2011** |
| Weedy check | 1137 f | 1006 f | 61398 | 54318 |
| Hand Weeding | 1527 a | 1401 a | 71955 | 65157 |
| Haloxyfop 10.8 EC@ 108 g a.i. $ha^{-1}$ | 1373 bc | 1322bc | 71647 | 68907 |
| Barley water extract (BWE) @ 20 L $ha^{-1}$ | 1246 de | 1143 e | 65460 | 59919 |
| Brassica water extract (BrasWE) @ 20 L$ha^{-1}$ | 1207 ef | 1086 e | 63606 | 57035 |
| BWE + BrasWE @ 10+10 L $ha^{-1}$ | 1273cde | 1224d | 67023 | 64408 |
| BWE + BrasWE @ 10+10 L $ha^{-1}$ + Haloxyfop 10.8 EC @ 27 g a.i. $ha^{-1}$ | 1338 bcd | 1273 cd | 70888 | 67343 |
| BWE + BrasWE @ 10+10 L $ha^{-1}$ + Haloxyfop 10.8 EC @ 54 g a.i. $ha^{-1}$ | 1378 b | 1355ab | 72496 | 71246 |
| BWE + BrasWE @ 10+10 L $ha^{-1}$ + Haloxyfop 10.8 EC @ 81 g a.i. $ha^{-1}$ | 1409 b | 1368 ab | 73663 | 71443 |
| LSD at α 5% | 101.1 | 70.8 | | |

Means sharing same letters are non significant at α = 5%.

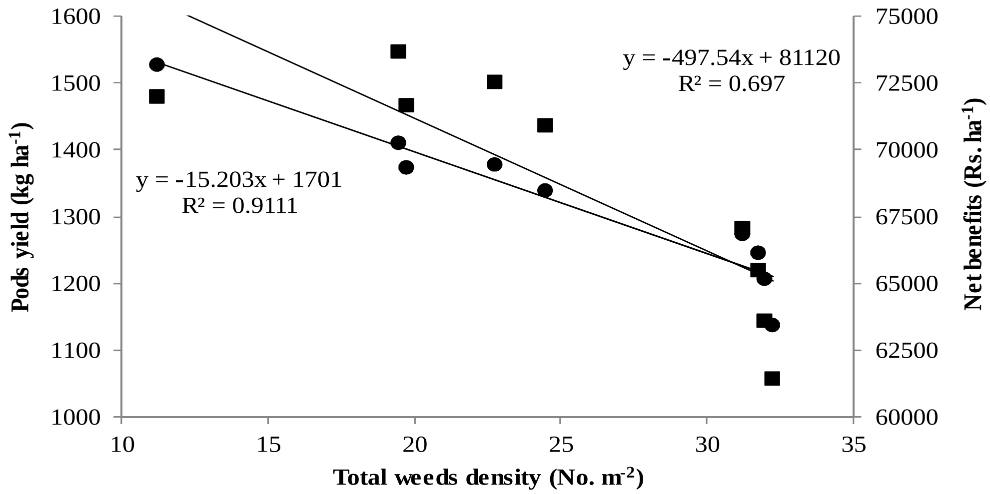


**Figure 1. Relationship of pods yield (kg ha$^{-1}$) and net benefits (Rs. ha$^{-1}$) with total weeds density (No. m$^{-2}$) in groundnut crop during 2009.**

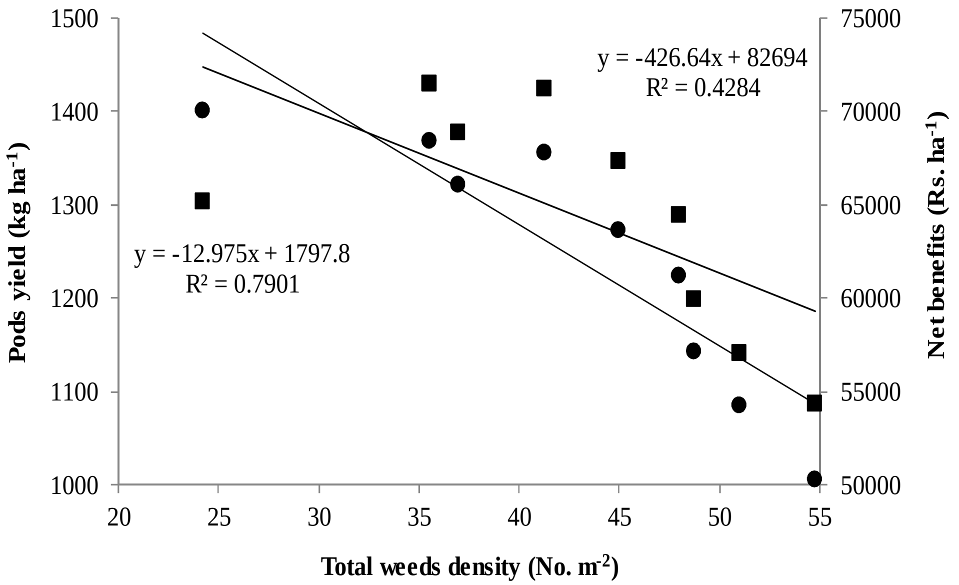


**Figure 2. Relationship of pods yield (kg ha$^{-1}$) and net benefits (Rs. ha$^{-1}$) with total weeds density (No. m$^{-2}$) in groundnut crop during 2011.**

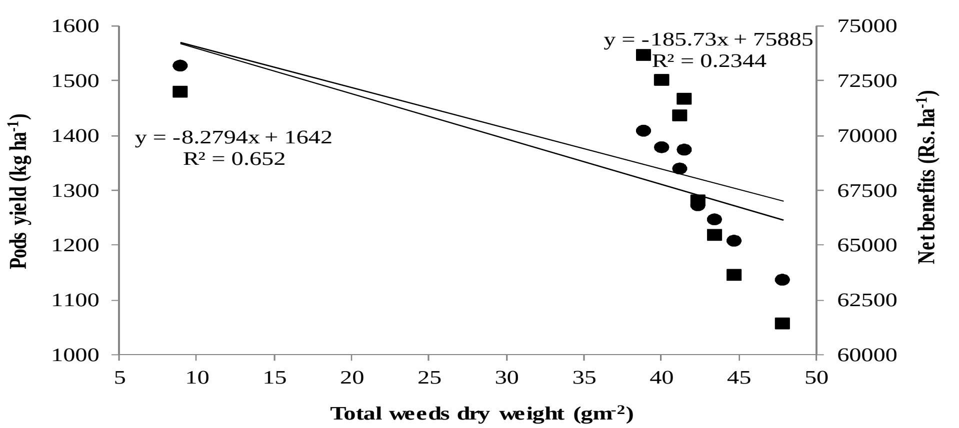


**Figure 3. Relationship of pods yield (kg ha$^{-1}$) and net benefits (Rs. ha$^{-1}$) with total weeds dry weight (g m$^{-2}$) in groundnut crop during 2009.**

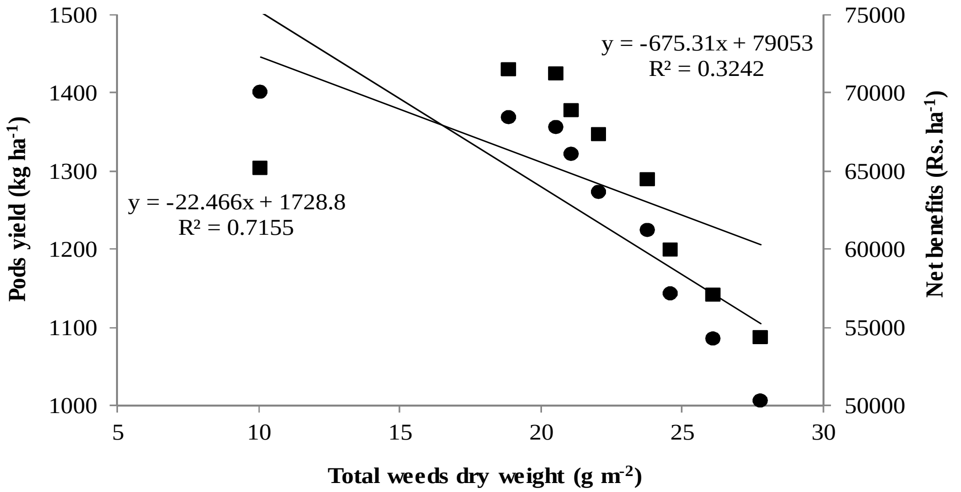


**Figure 4. Relationship of pods yield (kg ha$^{-1}$) and net benefits (Rs. ha$^{-1}$) with total weeds dry weight (g m$^{-2}$) in groundnut crop during 2011.**

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