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BIO-EFFICACY EVALUATION OF HERBICIDES MIXTURES FOR WEED MANAGEMENT IN GROUNDNUT (*Arachis hypogaea* L.)

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ABSTRACT

A field experiment was conducted on groundnut at Farm Research Station, Araul of C.S. Azad University of Agriculture & Technology, Kanpur (U.P.), India; during *summer* and *kharif* seasons of 2021 to evaluate herbicides mixtures for efficient weed management. Eight treatments, *i.e.*; T_1, quizalofop ethyl 7.5% + imazethapyr 15% EC @ 312.5 ml/ha; T_2, quizalofop ethyl 7.5% + imazethapyr 15% EC @ 375.0 ml/ha; T_3, quizalofop ethyl 7.5% + imazethapyr 15% EC @ 437.5 ml/ha; T_4, quizalofop ethyl 5% EC @ 1000.0 ml/ha; T_5, imazethapyr 10% SL @ 1500.0 ml/ha; T_6, imazamox 35% + imazethapyr 35% WG @ 100.0 gm/ha; T_7, 2 manual weedings and T_8, weedy check were tested in randomized block design. Groundnut variety 'DH-86' was used in the experiment. Crop was raised with recommended package of practices except treatments. Based on pooled data over two seasons, among herbicidal treatments, application of quizalofop ethyl 7.5% + imazethapyr 15% EC @ 437.5 ml/ha reduced the weed count of *Echinochloa* spp., *Digitaria sanguinalis*, *Dactyloctenium aegyptium*, *Digera arvensis*, *Commelina bengalensis*, *Cyperus difformis* and other weeds by 62.44, 72.69, 67.53, 64.36, 74.46, 68.72 and 73.23% and recorded dry weight of 1.69, 0.71, 0.95, 1.28, 0.71, 0.87 and 1.50g, respectively. This treatment also registered highest and notable values of weed control efficiency in all species of weeds and produced significantly highest pod yield (2.23 t/ha) as well as haulm yield (2.75 t/ha). Thus, this practice proved to be most suitable for realizing optimum pod yield and efficient management of weeds in groundnut.

Key words : Groundnut, Pod yield, Weed control efficiency, Weed population.

Introduction

Oilseed cultivation is undertaken across the country in about 28.83 million ha, largely under rainfed areas covering 68% and producing around 35.95 million tonnes of oilseeds during 2020-21. Among nine major oilseeds, soybean (33.5%), groundnut (30%) and rapeseed & mustard (27%) contribute more than 90% of total oilseeds production in the country. However, in terms of vegetable oil production mustard, soybean and groundnut contribute 27, 34 and 30%, respectively. Rajasthan, Madhya Pradesh, Maharashtra and Gujarat are the major oilseed producing states contributing more than 76% of oilseeds production in the country (Anonymous, 2022).

Groundnut is a major oilseed crop in India and plays a major role in bridging the vegetable oil deficit in the country. Groundnut is not only an important oilseed crop of India but also an important agricultural export commodity. With annual, all season coverage of 31.6 million hectares globally; India ranks first in groundnut acreage and is the second largest in the world with 10.24 million tonnes production and productivity of 1703 kg per hectare in 2020-21 (Anonymous, 2021). Groundnut in India is available throughout the year due to a two-crop cycle. During crop growth, many weeds cause losses in groundnut yield by competing for water, space, light and nutrients. It is necessary to maintain the crops in a weed-

free condition during the critical period for crop-weed competition to maintain high yields (Islam *et al*., 2016). Each of the agro-ecological regions and crops grown has distinct weed problems (Rao *et al.*, 2014). Jalendhar *et al*. (2016) stated that the weeds are one of the major biological constraints that limit crop productivity in India. Weeds are the silent robbers of plant nutrients, moisture, sunlight and also compete for space that would otherwise be available to the main crop. Herbicides are among the most widely used agrochemical products globally, followed by insecticides and fungicides (FICCI, 2013).

Weed management practice must be economically and ecologically affordable to farmers. As labour for manual weeding became expensive and scarce, there is need to develop of region specific herbicide based weed management practice for different geographical and agro-climatic regions. Therefore, the current study includes weed management with post-emergence herbicides mixtures to evaluate its influence on productivity and profitability of groundnut.

Materials and Methods

A field experiment was conducted on groundnut at Farm Research Station, Araul of C.S. Azad University of Agriculture & Technology, Kanpur (U.P.), India; during *summer* and *kharif* seasons of 2021. The soil is sandy loam in texture with pH was 7.8. The soil was medium in organic carbon (0.52%), available N (203.4 kg/ha), available P (23.6 kg/ha) and available K (212.8 kg/ha) at initiation of experiment. Eight treatments comprising T_1, quizalofop ethyl 7.5% + imazethapyr 15% EC @ 312.5 ml/ha; T_2, quizalofop ethyl 7.5% + imazethapyr 15% EC @ 375.0 ml/ha; T_3, quizalofop ethyl 7.5% + imazethapyr 15% EC @ 437.5 ml/ha; T_4, quizalofop ethyl 5% EC @ 1000 ml/ha; T_5, imazethapyr 10% SL @ 1500.0 ml/ha; T_6, imazamox 35% + imazethapyr 35% WG @ 100 g/ha; T_7, 2 manual weedings (at 30 and 60 days after crop sowing) and T_8, weedy check were evaluated in randomized block design with three replications. Groundnut variety 'DH-86' was sown at 30x10 cm spacing on 17 March, 2021 and 8 July, 2021 for *summer* and *kharif* season, respectively. Seeds were treated with carbendazim a systemic fungicide containing 50% WP @ 2.5 g/kg seed before sowing of the seed for the protection of crop plants from seed borne diseases. The plot size of 3.0 × 5.0 m was maintained. The weed management practices were done as per treatment. Other package of practices recommended for the region was also followed uniformly in all the experimental plots. The herbicides were applied as post-emergence at 20 days after crop sowing with surfactant using knapsack sprayer fitted with flat fan nozzle. Water volume of 375 lit/ha was used for herbicidal spray. Observations for weed population were recorded at 30 days after spray of herbicides (50 days after crop sowing) with the help of four randomly selected quadrats of 0.25 m^2 (50×50 cm) per plot to evaluate the efficiency of herbicides. The weed population was counted in numbers. The species wise weeds were dried in oven at 70°C temperature for three days to record dry weight. Since data recorded on weed population and weed dry weight do not follow normal distribution, so the data were transformed using square root $\sqrt{x} + 0.5$ transformation and then statistically analysed (Singh *et al.*, 2021). Weed control efficiency (WCE), herbicide efficiency index (HEI), weed persistence index (WPI) and relative density (RD) were calculated as per method suggested by Devasenapathy *et al*. (2008). The observations were also taken on their pod and haulm yields of groundnut and subjected to analysis of variance with mean comparison of 5% level of significance.

Results and Discussion

Weed population

A total number of six major weed species, *i.e.* three grasses, two broadleaf and one sedge weeds were identified in the experimental field at 50 days after sowing. Among the grassy weeds, *Echinochloa* spp., *Digitaria sanguinalis* and *Dactyloctenium aegyptium* were the most prominent weeds. In case of broadleaf weeds, *Digera arvensis* and *Commelina bengalensis* were prominent whereas, *Cyperus difformis* was the only prominent sedge. Beside them, other weed species were also present in a very low population.

Different weed management treatments proved effective in reducing the number of weeds significantly compared to weedy check at 50 days after sowing (Table 1). Based on pooled data over two seasons, the highest populations of all the weed species were recorded under the treatment of weedy check. Whereas, among herbicidal treatments, application of combination of quizalofop ethyl 7.5% + imazethapyr 15% EC @ 437.5 ml/ha significantly reduced the population of all the weed species and recorded lowest population of *Echinochloa* spp. (1.54), *Digitaria sanguinalis* (0.71), *Dactyloctenium aegyptium* (1.00), *Digera arvensis* (1.34), *Commelina benghalensis* (0.71), *Cyperus difformis* (1.27) and other weeds (1.17). It was followed by quizalofop ethyl 7.5% + imazethapyr 15% EC @ 375.0 ml/ha in terms of weed population of all species. It might be attributed to efficient control of weeds in the crop due to herbicidal action.

Application of quizalofop ethyl 7.5% + imazethapyr 15% EC @ 437.5 ml/ha reduced *Echinochloa* spp.,

Table 1 : Effect of treatments on weed count and their reduction (%, in parenthesis) and weed dry weight (g) in groundnut at 50 DAS (pooled data over 2 seasons).

Treatment	Weed population (No.)/0.25 m²							Weed dry weight (g)						
	Grassy weeds			Broadleaf weeds		Sedge weeds	Others	*Echinochloa* spp.	*Digitaria sanguinalis*	*Dactyloctenium aegyptium*	*Digera arvensis*	*Commelina benghalensis*	*Cyperus difformis*	Other weeds
	Echinochloa spp.	*Digitaria sanguinalis*	*Dactyloctenium aegyptium*	*Digera arvensis*	*Commelina bengalensis*	*Cyperus difformis*								
Quizalofop ethyl 7.5%+ imazethapyr 15% EC @ 312.5 ml/ha	2.27 (44.63)	1.17 (55.00)	1.74 (43.51)	2.11 (43.88)	1.39 (50.00)	1.77 (56.40)	2.26 (48.28)	2.28	1.16	1.74	1.84	1.32	1.11	2.71
Quizalofop ethyl 7.5%+ imazethapyr 15% EC @ 375 ml/ha	2.04 (50.24)	1.05 (59.61)	1.27 (58.77)	1.68 (55.32)	0.88 (68.34)	1.47 (63.79)	1.56 (64.30)	2.05	1.11	1.28	1.57	0.92	0.95	2.17
Quizalofop ethyl 7.5%+ imazethapyr 15% EC @ 437.5 ml/ha	1.54 (62.44)	0.71 (72.69)	1.00 (67.53)	1.34 (64.36)	0.71 (74.46)	1.27 (68.72)	1.17 (73.23)	1.69	0.71	0.95	1.28	0.71	0.87	1.50
Quizalofop ethyl 5% EC @ 1000 ml/ha	2.34 (42.93)	1.17 (55.00)	1.64 (46.75)	2.27 (39.63)	1.46 (47.48)	2.26 (44.33)	2.09 (52.17)	2.66	1.24	1.63	2.03	1.47	1.27	2.41
Imazethapyr 10% SL @ 1500 ml/ha	2.2 (46.34)	1.68 (35.38)	1.48 (51.95)	2.54 (32.45)	1.56 (43.88)	2.16 (46.80)	1.94 (55.61)	2.48	1.57	1.48	2.10	1.48	1.30	2.44
Imazamox 35% + imazethapyr 35% WG @ 100 g/ha	2.11 (48.54)	1.46 (43.85)	1.46 (52.60)	2.20 (41.49)	1.76 (36.69)	1.93 (52.46)	1.66 (62.01)	2.24	1.49	1.66	1.88	1.43	1.16	2.23
2 manual weedings	1.00 (75.61)	0.88 (66.15)	0.71 (76.95)	0.88 (76.60)	1.05 (62.23)	0.71 (82.51)	1.17 (73.23)	0.89	0.86	0.71	0.92	0.89	0.71	1.13
Weedy check	4.10 (0)	2.60 (0)	3.08 (0)	3.76 (0)	2.78 (0)	4.06 (0)	4.37 (0)	5.93	2.57	4.22	4.65	2.80	2.63	5.57
SEm ±	0.22	0.13	0.25	0.13	0.21	0.26	0.23	0.25	0.15	0.22	0.10	0.14	0.08	0.20
CD (P=0.05)	0.67	0.39	0.75	0.39	0.62	0.78	0.68	0.76	0.45	0.66	0.30	0.43	0.25	0.62

*Original values were transformed to $\sqrt{x + 0.5}$

Digitaria sanguinalis, *Dactyloctenium aegyptium*, *Digera arvensis*, *Commelina benghalensis* and *Cyperus difformis* by 62, 73, 68, 64 74 and 69% respectively, in comparison to weedy plots (Table 1). The population of other weeds was 73.23% less in number. None of the herbicidal treatments provided complete population reduction. This might be due to the redeveloping capability of weeds. Similar results were also reported by Zahan *et al*. (2017) in transplanted rice. On the other hand, the lowest population reduction of *Echinochloa* spp. (42.93%) and *Cyperus difformis* (44.33%) was recorded under quizalofop ethyl 5% EC @ 1000 ml/ha, *Digitaria sanguinalis* (35.38%) and *Digera arvensis* (32.45%) in imazethapyr 10% SL @ 1500 ml/ha, *Dactyloctenium aegyptium* (43.51%) and other weeds (48.28%) in quizalofop ethyl 7.5% + imazethapyr 15% EC @ 312.5 ml/ha and *Commelina benghalensis* (36.69%) in imazamox 35% + imazethapyr 35% WG @ 100 g/ha. Data in Table 1 shows that treatments of single herbicide were not effective in weed control due to presence of complex of the weed species in the field. Chauhan (2012) reported similar finding.

Weed Dry weight

Similar to weed population, different weed management practices also proved effective in reducing the dry weight of weeds significantly as compared to weedy check at 50 days after sowing (Table 1). Based on pooled data over two seasons, the results of the study clearly indicated that the dry weight of all weed species, except *Digitaria sanguinalis* and *Commelina benghalensis*, was quite low in the 2 manual weedings treatment. But, among herbicidal treatments, combination of quizalofop ethyl 7.5% + imazethapyr 15% EC @ 437.5 ml/ha recorded significantly lowest value of dry weight of *Echinochloa* spp. (1.69g), *Digitaria sanguinalis* (0.71g), *Dactyloctenium aegyptium* (0.95g), *Digera arvensis* (1.28g), *Commelina bengalensis* (0.71g), *Cyperus difformis* (0.87g) and other weeds (1.50g). It was followed by quizalofop ethyl 7.5% + imazethapyr 15% EC @ 375 ml/ha in terms of dry weight of all weeds species. In case of other treatments, the higher value of dry weight might be due to continuous growth of weeds throughout the crop season attached with more competitive capability than crop that was approximately entirely smother due to accelerated growth of weeds (Singh *et al*., 2021). Two manual weedings treatment recorded better weed management due to uprooting of weeds and thus, reducing the dry weight. These results were in harmony with Venkata *et al.* (2017) and Singh *et al*. (2021) findings in mungbean.

Weed control efficiency (WCE)

Weed control efficiency (WCE) varied appreciably under various weed management practices (Table 2). The 2 manual weedings treatment offered the highest weed control efficiency to *Echinochloa* spp. (98.94%), *Dactyloctenium aegyptium* (100.00%), *Digera arvensis* (97.97%), *Cyperus difformis* (100.00%) and other weeds (97.12%), but the highest WCE for *Digitaria sanguinalis* (100.00%) and *Commelina benghalensis* (100.00%) was recorded with the application of quizalofop ethyl 7.5% + imazethapyr 15% EC @ 437.5 ml/ha. However, the practice of manual weeding is not economically and ecologically affordable to the farmers.

Among herbicidal treatments, application of quizalofop ethyl 7.5% + imazethapyr 15% EC @ 437.5 ml/ha registered highest and notable values of weed control efficiency in all species of weeds. This highest weed control efficiency might be because of lowest weed population at the stage of critical crop-weed competition as compared to all other herbicidal treatments. Singh *et al.* (2021) reported similar finding. On the contrary, the lowest weed control efficiency of *Digitaria sanguinalis* (67.86%), *Digera arvensis* (81.52%), *Commelina benghalensis* (76.36%) and *Cyperus difformis* (81.44%) were obtained under imazethapyr 10% SL @ 1500 ml/ha while, *Dactyloctenium aegyptium* (84.99%) and other weeds (77.39%) with quizalofop ethyl 7.5% + imazethapyr 15% EC @ 312.5 ml/ha and *Echinochloa* spp. (80.83%) with quizalofop ethyl 5% EC @ 1000 ml/ha. This lower weed controlling efficiency of different sole or combination herbicides might be related to the less control of concern weeds. Kumar *et al.* (2017) were also found similar results.

Herbicide efficiency index (HEI) and weed persistence index (WPI)

Herbicide efficiency index (HEI) indicates the weed killing potential of different herbicidal treatments and their phytotoxicity on the crop and weed persistence index (WPI) is used to indicate the resistance of weeds against various tested treatments. Herbicide efficiency index and weed persistence index varied with the treatments (Table 2). Application of quizalofop ethyl 7.5% + imazethapyr 15% EC @ 437.5 ml/ha registered the highest HEI (0.022), which was significantly higher rest of the tested treatments, indicating the higher yield advantage. Among herbicidal treatments, the highest WPI of 0.88 was observed in quizalofop ethyl 7.5% + imazethapyr 15% EC @ 375.0 ml/ha (0.88), however, all the herbicidal treatments were found statistically at par with each other in terms of WPI.

Table 2 : Effect of treatments on weed control efficiency (WCE), relative density of weeds, herbicide efficiency index and weed persistence index in groundnut (pooled data over 2 seasons).

Treatment	Weed control efficiency (%)							Relative density (%)				Herbicide efficiency index (HEI)	Weed persistence index (WPI)
	Echinochloa spp.	*Digitaria sanguinalis*	*Dactyloctenium aegyptium*	*Digera arvensis*	*Commelina benghalensis*	*Cyperus difformis*	Other weeds	Grassy weeds	Broad leaf weeds	Sedge weeds	Others		
Quizalofop ethyl 7.5%+imazethapyr 15% EC @ 312.5 ml/ha	86.35	84.67	84.99	86.39	80.57	88.14	77.39	40.75	27.54	13.93	17.78	0.004	0.83
Quizalofop ethyl 7.5%+imazethapyr 15% EC @ 375 ml/ha	89.31	86.79	92.21	90.60	93.89	93.29	86.21	43.82	25.73	14.77	15.68	0.013	0.88
Quizalofop ethyl 7.5%+imazethapyr 15% EC @ 437.5 ml/ha	91.66	100.00	97.00	94.61	100.00	95.79	93.22	41.99	26.48	16.41	15.12	0.022	0.87
Quizalofop ethyl 5% EC @ 1000 ml/ha	80.83	80.59	87.01	82.70	77.31	82.37	82.40	38.93	28.19	17.08	15.80	0.006	0.84
Imazethapyr 10% SL @ 1500 ml/ha	83.64	67.86	88.57	81.52	76.36	81.44	81.82	39.53	30.23	15.93	14.31	0.007	0.83
Imazamox 35% + imazethapyr 35% WG @ 100 g/ha	86.92	71.94	86.84	85.63	78.80	86.58	85.16	39.98	31.78	15.34	13.19	0.008	0.84
2 manual weedings	98.94	95.27	100.00	97.97	95.65	100.00	97.12	40.47	30.16	11.09	18.28	-	0.83
Weedy check	-	-	-	-	-	-	-	39.51	26.42	16.40	17.66	-	1.00
SEm±	-	-	-	-	-	-	-	1.04	0.97	0.39	0.44	0.0007	0.03
CD (P=0.05)	-	-	-	-	-	-	-	3.10	2.88	1.16	1.30	0.002	0.09

Table 3 : Effect of treatments on yield and economics of groundnut (pooled data over 2 seasons).

Treatment	Pod yield (t/ha)	Haulm yield (t/ha)	Economics (increase with treatment over control)		
			Expenditure (x10³ `/ha)	Net profit (x10³`/ha)	Return per rupee invested (`)
Quizalofop ethyl 7.5% + imazethapyr 15% EC @ 312.5 ml/ha	1.68	2.29	1.98	7.82	3.95
Quizalofop ethyl 7.5% + imazethapyr 15% EC @ 375 ml/ha	2.05	2.61	2.14	20.61	9.64
Quizalofop ethyl 7.5% + imazethapyr 15% EC @ 437.5 ml/ha	2.23	2.75	2.29	26.76	11.66
Quizalofop ethyl 5% EC @ 1000 ml/ha	1.75	2.39	2.50	9.75	3.90
Imazethapyr 10% SL @ 1500 ml/ha	1.82	2.56	2.25	12.45	5.53
Imazamox 35% + imazethapyr 35% WG @ 100 g/ha	1.87	2.34	2.74	13.71	5.01
2 manual weedings	2.32	2.50	7.81	24.39	3.12
Weedy check	1.40	1.87	-	-	-
SEm±	0.06	0.07	0.11	0.58	0.23
CD (P=0.05)	0.17	0.22	0.33	1.72	0.68

* Sale price @ Rs 35000/t.

Relative density (RD)

The relative density of weeds influenced significantly by different treatments (Table 2). Among the herbicides, the grasses (38.93%), broadleaf weeds (25.73%), sedges (13.93%) and other weeds (13.19%) were the least dominant in quizalofop ethyl 5% EC @ 1000 ml/ha, quizalofop ethyl 7.5% + imazethapyr 15% EC @ 375.0 ml/ha, quizalofop ethyl 7.5% + imazethapyr 15% EC @ 312.5 ml/ha and imazamox 35% + imazethapyr 35% WG @ 100 g/ha, respectively. The lower weed density reduces the weed competition.

Productivity

Groundnut pod and haulm yield was influenced significantly by different treatments (Table 3). Herbicide alone or in combination proved better for pod and haulm yield than the weedy check. Based on pooled data over two seasons, though 2 manual weedings treatment produced highest pod yield of 2.32 t/ha, but among tested herbicidal treatments, application of quizalofop ethyl 7.5% + imazethapyr 15% EC @ 437.5 ml/ha recorded highest pod yield (2.23 t/ha), which was significantly higher than rest of the treatments. However, both treatments were statistically at par with each other in terms of pod yield. Moreover, manual weeding became expensive due to scarcity of labour. The increase in pod yield with herbicides mixture might be due to the significant reduction in population and dry weight of weeds, which consequently resulted in higher yield. These results corroborate with the findings of Rajiv and Singh (2018). In case of haulm yield, quizalofop ethyl 7.5% + imazethapyr 15% EC @ 437.5 ml/ha registered highest haulm yield of 2.75 t/ha followed by quizalofop ethyl 7.5% + imazethapyr 15% EC @ 375.0 ml/ha with 2.61 t/ha. The lowest pod yield (1.40 t/ha) and haulm yield (1.87 t/ha) were observed under weedy check. It might be attributed to the insufficient availability of nutrients, soil moisture and light for crop use. Similar results were also reported by Zahan *et al*. (2017).

Economics

The data depicted in Table 3 revealed that the increase in expenditure due to treatment over control was lowest in quizalofop ethyl 7.5% + imazethapyr 15% EC @ 312.5 ml/ha (` $1.98 \times 10^3$/ha) and highest in 2 manual weedings (` 7.81×10^3/ha), which might be attributed to higher cost of labour. The increase in net returns registered significantly highest with quizalofop ethyl 7.5% + imazethapyr 15% EC @ 437.5 ml/ha (` $26.76 \times 10^3$/ha) followed by 2 manual weedings (` 24.39×10^3/ha) and quizalofop ethyl 7.5% + imazethapyr 15% EC @ 375 ml/ha (` 20.61×10^3/ha). Return per rupee invested on treatment was worked out highest of 11.66 in quizalofop ethyl 7.5% + imazethapyr 15% EC @ 437.5 ml/ha. These results are in close agreement to the findings of Rajiv (2019).

Two seasons continuous study on bio-efficacy evaluation of herbicides mixtures for weed management in groundnut cv. DH-86 revealed that the application of quizalofop ethyl 7.5% + imazethapyr 15% EC @ 437.5 ml/ha was found suitable for realizing optimum pod yield (2.23 t/ha) and efficient weed management.

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