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Impact of Chemical Weed Control on Green Fodder Yield of Berseem (*Trifolium alexandrinum* L.) and Soil Environment- a Review

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Abstract

Berseem is a widely grown winter/rabi fodder crop in India. Thirty-eight weed species of 16 plant families were identified from different sites in India. Cichorium intybus is the dominant weed species, identified from almost all the sites. Whereas, Amaranthus viridis was positive indicator species for Rahuri; Chenopodium album negative indicator species for of Pantnagar and Ranchi; Anagallis arvensis positive indicator for Jhansi and Hissar sites. Weed infestation causes 25-50 per-cent yield (green fodder & seed) losses. Butachlor, trifluralin, fluchloralin, imazethapyr, oxyflourfen, and pendimethalin were used for the chemical control of weed flora in the berseem crop. Butachlor persists up to 100, Fluchloralin 243, Imazethapyr 90-240, Oxyflourfen 60-80, and Pendimethalin 60-200 days in soil. Butachlor has 5-24, Fluchloralin 12-46, Imazethapyr 57-71, Oxyflourfen 12-29 and Pendimethalin 55-77 days' half-life. The application of herbicides influences soil environment by affecting soil flora and fauna. However, the chemical weed control method has environmental hazards, this is a widely accepted method due to its cost-effectiveness and timely control of weed flora. It also cut down the yield losses.

Keywords: *Berseem, weed flora, TWINSPAN analysis, weed management, persistence in soil, half-life, economic impact*

Introduction

Egyptian clover, commonly known as berseem (*Trifolium alexandrinum* L.), is one of the most important leguminous winter fodder crops in India and also is known as '*King of the Fodders*'. It is cultivated in India, Turkey, Egypt, Pakistan and countries of the Mediterranean region. In India, the crop is grown in the North, Central, Northwestern, and Northeastern regions and occupies around 2 million-hectare area [30] [39] [20]. Being an important winter/rabi fodder crop, it produces soft and succulent fodder over a long period, from November to May in 4-5 cuttings under irrigated conditions [32]. A slow growth rate during the initial 60-70 DAS (Days After Sowing) allows fast growth of weeds [26] [43]. *Cichorium intybus*, *Cornopus didimus*, *Spergula arvensis*, *Chenopodium album*, *Rumex dentatus*, *Melilotus indica*, *Medicago denticulata*, *Lathyrus aphaca* among broad-leaf weeds and *Phalaris minor*, *Polypogon monspeliensis* and *Poa annua* among the grassy weeds mainly infested the berseem crop [26] [56]. Severe weed infestation causes 30-40 % loss in green fodder yield [12]. Applying chemicals in the field causes soil and water pollution [37] [36] [27] and incurred high costs for the production of fodder. Applying chemicals causes a loss of biodiversity [58] [35]and causes harm to the animals on which they will feed [38]. Therefore, weed control during the initial period of crop growth is essential to reduce fodder yield losses. Manual and mechanical weeding operations are effective weed control methods but they are labor-intensive and costlier. Hence, weed control by using chemicals provide greater flexibility and minimize labor cost, makes management of labor easy and most notably, decrease the risk of mishaps by plummeting exhaustion and worker's exposure to sharp implements and power equipment.

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Weed flora of berseem crop

Weed species (38) from 16 families viz., Aizoaceae, Amaranthaceae, Asteraceae, Brassicaceae, Caryophyllaceae, Commelinaceae, Cyperaceae, Euphorbiaceae, Fabaceae, Malvaceae, Poaceae, Polygonaceae, Portulacaceae, Primulaceae, Solanaceae, Verbenaceae were identified by many researchers from different climatic conditions and soil types (Table 1). More than 55% weed species belongs to Fabaceae family (08), Poaceae (07) and Asteraceae (06).

TWINSPAN analysis was carried out for weed flora identified by many researchers from different soil and climatic conditions in India (Figure 1). At first level, *Amaranthus viridis* [+] was identified at only Rahuri (1 & 2) sites, therefore *A. viridis* known as positive indicator species for Rahuri (1 & 2) sites. At second level, *Chenopodium album* [-] was not identified from 2 sites of Pantnagar and 1 site of Ranchi. Therefore, *C. album* know to be negative indicator species for these sites. At third level, *Anagallis arvensis* [+] was identified from Jhansi and Hissar sites, therefore *A. arvensis* was the positive indicator species for these sites.

Losses caused due to weed

Cichorium intybus is associated species of berseem and compete for essential nutrients, light, moisture and space [56] [45] [26]. Weed competition substantially reduces the green forage yield up to 30-40 per cent [12], besides deteriorating quality of green forage, if not controlled during critical period of crop – weed competition. The contamination of produce with weeds and weed seeds reduces the crop quality. Weeds decrease the acceptability of fodder and pose problems in harvesting of the crop [60] [57] noticed that the green forage yield reduced by 25-30 per cent due to infestation of weeds and it also deteriorate the quality of berseem seeds. According to the [1] [15], weeds not only deteriorate fodder quality but also decrease fresh fodder yield 23-30 per cent and seed yield up to 50 per cent in silty loam soil. Infestation of weed flora reduces green fodder (23-28 per cent) and seed (38-44 per cent) yield fodder due to slow growth of crop [62].

Chemical weed control strategies

Weeds are the major impediment to crop production through their ability to compete for resources such as space, nutrients, water and solar redaction, etc and their impact on the quality of yield. Traditionally, weed control methods in India has been largely dependent on manual weeding. Manual and mechanical weeding operations are effective methods but they are labor-intensive and costlier [16]. Low availability of labor in the agricultural sector not only enhances the cost of production but also severely affects the timely weeding operations. It results in the reduction of both the quality and quantity of berseem fodder and seed. Under such a situation, herbicidal weed control offers a better alternative to manual and mechanical weeding so it is felt necessary to evaluate pre and post-emergence herbicides alone and in combination which may be the best alternative to the traditional practices [57] [26] [33] [59].

Effect of herbicide on weeds and weed control efficiency

In the silty clay loam soil of Pantnagar, a maximum and significant decrease (30.8 per cent) in weed dry weight was recorded from the pre-emergence application of butachlor @ 1.0 kg a.i./ha compared with other herbicidal treatments, which was at par with butachlor @ 2.0 kg a.i./ha and seed treatment with 10 per cent salt solution [15]. Furthermore, [19] evaluated butachlor, trifluralin, fluchloralin, and imazethapyr and reported that imazethapyr at 0.10 and 0.15 kg/ha PRE was most effective against *Cichorium intybus* with 74 per cent weed control efficiency. At Rahuri (Maharashtra), among weed control chemicals pre-emergence application of oxyflourfen @ 0.100 kg a.i./ha *fb* post emergence application of imazethapyr @ 0.100 kg a.i./ha immediate after harvest of 1st cut recorded lowest total weed count/m^2 and its total dry weight at harvest as compared to rest of the treatments. They also found that the maximum weed control efficiency (67.88 per cent) with oxyflourfen @ 0.100 kg a.i./ha *fb* imazethapyr @ 0.100 kg a.i./ ha [24] [44]. Similarly, [1] noticed that in the silty clay loam soil of Pantnagar, Uttarakhand observed that application of oxyfluorfen @ 0.10 kg/ha was better for suppressing density of *Medicago denticulata* L. and had significantly less weed index. It also reported that application of pendimethalin @ 1.0 kg/ha+imazethapyr @ 0.15 kg/ha (Immediately after 1st cut) reduced the total density of the weed compared to the remaining treatments. However, in the sandy clay loam soil of Jabalpur, pre-emergence application of oxyfluorfen @ 0.100 kg a.i./ha+imazethapyr @ 0.15 kg a.i./ha recorded significantly lowest total weed intensity (6.17/m^2)

Table 1: Weed flora of Berseem fields under different soil and climatic conditions

Sl. No	Soil	Climatic conditions	Weed flora	Source
1	Silty loam soil of Pantnagar (Uttara-khand)	Humid subtropical climate zone	*Cichorium intybus, Trianthema portulacastrum, Poa annua, Coronopus didymus* and *Cyperus rotundus*	[15]
2	Silty clay loam soil of Pantnagar (Ut-tarakhand)	Humid subtropical climate zone	*Polygonum spp., Medicago denticulata, Coronopus didymus, Cyperus rotundus, Cichorium intybus* and *Vicia spp.*	[26]
3	Sandy clay loam soil at IGFRI, [14] nsi	Sub-tropical, long & intensive hot summers, low and irregular [29] nfall, short and mild winter	*Anagallis arvensis, Chenopodium album, Cichorium intybus, Coronopus didymus, Eclipta alba, Medicago denticulata, Melilotus albus, Melilotus indicus, Physalis minima, Rumex dentatus, Sonchus asper, Spergula arvensis* and *Trifolium resupinatum*	[62]
4	Clay loam soil at IGFRI ([14]nsi)	Sub-tropical, long & intensive hot summers, low and irregular [29] nfall, short and mild winter	*Cichorium intybus, Cyperus rotundus, Cynodon dactylon, Melilotus indicus, Anagallis arvensis, Desmodium tortuo-sum, Spergula arvensis, Rumex longifolius, Tridax procum-bens* and *Chenopodium album*	[19]
5	Clay soil of Rahuri	Burning summer and mild winter characteriz-es climate of Rahuri	Major grassy (monocot) weeds were *Cynodon dactylon, Chloris barbata, Digitaria longiflora* and *Dactyloctenium aegyptium*; among broad-leaved (dicot) weeds *Amaranthus viridis, Euphorbia geniculata, Celosia argentea, Trianthe-ma portulacastrum, Commelina benghalensis, Corchorus aestuans, Parthenium hysterophorus, Tridax procumbens, Portulaca oleracea* and *Cichorium intybus*; and *Cyperus rotundus* from sedges	[44]
6	Western Maharash-tra (Rahuri)	Burning summer and mild winter characteriz-es climate of Rahuri	major grassy (monocot) weeds; *Cynodon dactylon, Chloris barbata, Digitaria longiflora* and *Dactyloctenium aegyp-tium*, among broad leaved (dicot) weeds; *Amaranthus viridis, Euphorbia geniculata, Celosia argentea, Lantana camara, Trianthema portulacastrum, Commelina benghalen-sis, Corchorus aestuans, Parthenium hysterophorus, Tridax procumbens, Portulaca oleracea* and *Cichorium intybus*, and *Cyperus rotundus* from sedges	[24]
7	Sandy loam soil of Ranchi	Humid subtropical climate	*Cichorium intybus, Medicago denticulata, Medicago hispida* and *Coronopus didymus*	[17]
8	Clay loam soil of Gurdaspur (Punjab)	Central plain agro cli-matic region of Punjab	*Cichorium intybus, Coronopus didymus, Spergula arvensis, Chenopodium album, Rumex dentatus, Melilotus indicus, Medicago denticulata Lathyrus aphaca* among broad-leaf weeds and *Phalaris minor, Polypogon monspeliensis* and *Poa annua*	[6]
9	Hissar (Haryana)	Continental climate, with very hot summers and relatively cool win-ters; scanty [29]nfall	*Coronopus didymus, Anagallis arvensis, Melilotus indicus, Lathyrus aphaca, Cirsium arvense, Cyperus rotundus, Che-nopodium album* and *Rumex dentatus*	[28]

and dry weight (5.92 g/m^2) of weeds as compared to other treatments. It also recorded higher weed control efficiency (72.31 per cent) [14]. At Pantnagar, [26] reported that pendimethalin @ 1.0 kg a.i./ha + imazethapyr @ 0.15 kg a.i./ha (Immediate after 1st cut) caused significant reduction in weed dry weight followed by imazethapyr @ 0.15 kg a.i./ha (Immediate after 1st and 2nd cut) which were statistically at par with pendimethalin @ 1.0 kg a.i./ha-PE, pendimethalin @ 1.0 kg a.i./ha-PE+ One hand weeding at 5 weeks after sowing and oxyflourfen @ 0.10 kg a.i./ha -PE+ One hand weeding at 5 weeks after sowing. In sandy loam soil of Ranchi, [17] observed that application of pendimethalin @ 0.4 kg a.i./ha resulted significantly lesser number of narrow-leaved weed/m^2 (22.66), broad-leaved weed/m^2 (11.0), sedges /m^2 (21.6) and total weed population /m^2 (54.66) which were at par with oxyflourfen @ 0.100 kg a.i./ ha+ imazethapyr @ 0.100 kg a.i./ ha immediate after harvest of 1st cut only. Similarly, [62] at IGFRI, Jhansi found that application of imazethapyr at 20 days after sowing @ 0.1 kg a.i./ha recorded significantly lowest weed

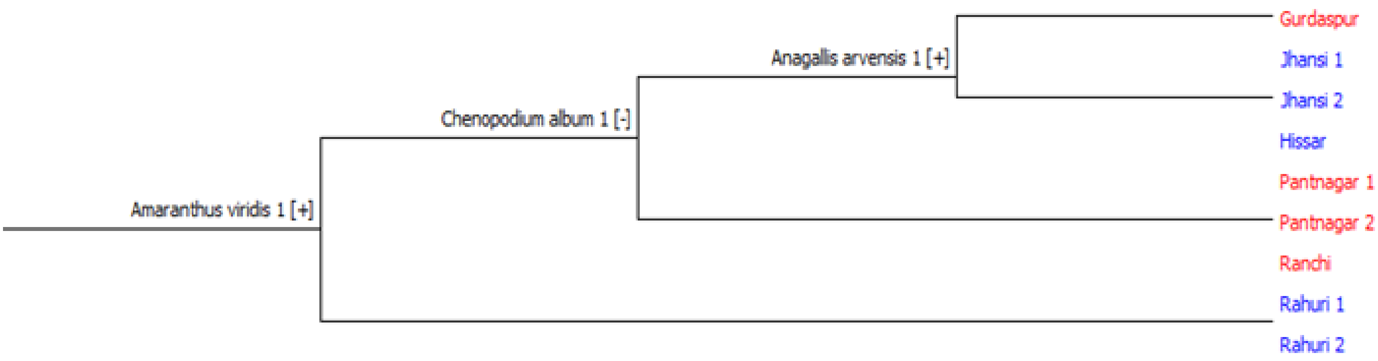

Figure 1: TWINSPAN analysis of weed flora identified form different soil and climatic conditions

intensity (4.66, 4.43, and 4.14/m^2), weed dry weight (3.29, 3.24, and 3.15 g/m^2) and highest weed control efficiency (82.49, 79.14, and 70.93 %) than weedy check and other herbicides treatments at first, second and third cut. At Gurdaspur, [6] observed that the lowest weed density (13.5 weeds/m^2) and biomass (10.2 g/m^2) were observed under fluchloralin 0.45 kg/ha *fb* imazethapyr 0.075 kg/ha closely followed by application of oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.075 kg/ha, which were significantly lower than all other herbicidal treatments. At Ranchi, [18] reported that application of pendimethalin @ 0.4 kg a.i/ha resulted significantly lower weed density (54.66/m^2) over other herbicidal control methods, which was *at par* with oxyflourfen @ 0.100 kg a.i/ ha+imazethapyr @ 0.100 kg a.i./ha applied immediate harvest of 1st cut only and also reported that weed control efficiency (80.22 %) was significantly higher due to pendimethalin @ 0.300 kg a.i/ ha+ imazethapyr @ 0.100 kg a.i/ ha, but *at par* with pendimethalin @ 0.4 kg a.i/ ha. Similarly, [28] at Hisar, Haryana reported that the minimum total weed density (3.4, 7.0, and 6.3 plants/m^2) and their dry weight (1.5, 2.6, and 3.0 g/m^2) at 30, 60 and 120 DAS was observed due to application of imazethapyr at 100 g/ha as post-emergence. It also recorded maximum weed control efficiency ranging between 69.7-77.3 per cent from 30 to 120 days after treatment (DAT) was obtained due to imazethapyr at 100 g/ha at 18 days after sowing followed by imazethapyr at 75 g/ha (67.7-75.8 per cent) and butachlor 1500 g/ha as pre-emergence (68.7-75.8 per cent).

Effect of herbicide on crop growth and growth attributes

In silty clay loam soil of Pantnagar, [15] observed that the growth attributing characters like plant height and the number of branches were maximum under pre-emergence application of butachlor @ 1.0 kg a.i./ ha. At Rahuri, [24] reported that plant height and L: S ratio was significantly maximum with treatment oxyflourfen @ 0.100 kg a.i.ha *fb* imazethapyr @ 0.100 kg a.i./ha immediate after harvest of 1st cut over rest of the treatments except oxyflourfen @ 0.100 kg a.i./ha and imazethapyr @ 0.100 kg a.i./ha (Immediate after harvest of 1st and 2nd cut). Similarly, [26] at Pantnagar, Uttarakhand reported that among herbicidal treatments imazethapyr @ 0.15 kg a.i./ha (Immediate after 1st and 2nd cut) treatment, being at par with oxyflourfen @ 0.10 kg a.i./ha + imazethapyr @ 0.15 kg a.i./ha (Immediate after 1st cut) and pendimethalin @ 1.0 kg a.i./ha-PE + one hand weeding at 5 weeks after sowing treatments, caused significantly more L: S ratio compared to remaining treatments. At Pune, Maharastra, the lowest weed dry matter yield (0.05 t/ha) and highest weed control efficiency (80.97 per cent) were recorded in sandy clay soil [16]. Furthermore, [62] found that plant height of berseem at harvest (57.59 cm) and dry weight recorded at all the three cuts (47.52, 55.17, and 64.50 g) was significantly higher by post-emergence application imazethapyr @ 0.1 kg a.i./ha over other chemicals weed management. However, [6] the experiment laid out at Gurdaspur (Punjab) and noticed that among the herbicidal treatments, fluchloralin 0.45 kg/ha *fb* imazethapyr 0.075 kg/ha, being at par with oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.075 kg/ha recorded significantly more number of tillers as compared to all other herbicidal treatments.

Effect of herbicide on crop yield and yield attributes

Application of fluchloralin @ 1.12 kg a.i./ha gave significantly higher green fodder yield of berseem than pendimethalin 1.0-1.5 kg a.i./ha a [20]. In silty loam soil of Pantnagar, [15] revealed that pre-emergence application of butachlor @ 1.0 kg a.i./ha was recorded significantly higher green fodder and dry fodder yields compared with other herbicidal treatments, which was at par with butachlor @ 2.0 kg a.i./ha and seed treatment with 10% salt solution. At Rahuri (Maharastra), all yield parameters *viz.*, green fodder yield, dry fodder yield, crude protein, straw yield, and seed were significantly higher due to oxyflourfen @ 0.100 kg a.i./ha *followed by* imazethapyr 0.100 kg a.i./ha immediate after harvest of 1st cut which was followed by treatment imazethapyr @ 0.100 kg a.i./ha (Immediate after harvest of 1st and 2nd cut) [24] [25]. Furthermore, [1] at Pantnagar, Uttarakhand reported that the application of oxyfluorfen @ 0.10 kg/ha + Imazethapyr @ 0.15 kg/ha (Immediately after 1st cut) caused significantly higher crude protein, green forage and dry fodder yields among herbicidal treatments. In the sandy clay loam soil of Jabalpur, [14] noticed that pre-emergence application of oxyfluorfen @ 0.100 kg a.i./ha+imazethapyr @ 0.15 kg a.i./ha had significantly higher green fodder yield (632.9 q/ha), dry fodder yield (95.6q/ha) and crude protein yield (14.878) as compared to other herbicidal treatments. Similarly, [26] the experiment laid out at Pantnagar, (Uttarakhand) during winter seasons of 2011-2012 and 2012-2013 and revealed that the total green forage (2283.80 q/ha), total dry forage (319.30 q/ha) and total crude protein yield (75.99 q/ha) was significantly more due to Imazethapyr @ 0.15 kg a.i./ha applied immediate after 1st and 2nd cut but seed yield was significantly more due to Oxyflourfen @ 0.10 kg a.i./ha + Imazethapyr @ 0.15 kg a.i./ha (Immediate after 1st cut) i.e. total 6.75 q/ha compared to remaining herbicidal treatments. In the sandy clay soil of Pune, [16] concluded that green fodder, dry matter, crude protein, straw and seed yields (34.39, 4.53, 0.81, 5.87 and 0.81 t/ha and respectively) were significantly higher in treatment combination of oxyflourfen 0.1 kg/ha + imazethapyr 0.1 kg/ha immediate after harvest of 1st cut. At Rahuri, [44] observed that the application of imazethapyr 0.1 kg/ha after 1st and 2nd cuts recorded significantly higher values of green forage yield (41.61 t/ha), seed yield (182 kg/ha), straw yield (1130 kg/ha), dry matter yield (6.90 t/ha) and crude protein yield (1278 kg/ha) than the rest of treatments. Furthermore, [62] reported that among all the herbicides treatments post- emergence application of imazethapyr @ 0.1 kg a.i./ha recorded maximum no. of effective tillers (291.07 /m^2), no. of heads (713.54/m^2) and no. of seeds/head (90.99). It also reported that due to application of imazethapyr @ 0.1 kg a.i./ha at 20 days after sowing caused significantly highest green fodder (404.45 q/ha), seed (3.50 q/ha) and straw (25.79 q/ha) yields than other herbicides treatments. However, in the sandy loam soil of Ranchi (Jharkhand), pre-emergence application of Pendimethalin @ 0.4 kg a.i./ha caused significantly higher green fodder yield (478.97 q/ha) and dry fodder yield (74.96 q/ha) than other herbicides treatments [18]. Furthermore, [6] at Gurdaspur, Punjab found that the maximum green fodder (98.64 t/ha) and seed yield (700 kg/ha) was recorded with fluchloralin 0.45 kg/ha *fb* imazethapyr 0.075 kg/ha, which was closely followed by the application of oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.075 kg/ha. At Hisar, [28] reported that the highest total green fodder yield (86.0 t/ha) was significantly higher due to the application of imazethapyr at 100 g/ha at 3 weeks after sowing over the rest of the treatments.

Persistence in soil

Herbicide is said to be persistent when it may be found to exist in the soil in its original or a closely related but phytotoxic form longer than one crop season after its original application [46]. The herbicide should persist long enough to check weeds until the end of critical period of weed competition but should not persist beyond the crop harvest, as it would be injurious to the sensitive crops grown in rotation [5] [7] [4]. The relative persistence in soil when applied at recommended rates for weed control and the half-life of some common herbicides are given in the Table 2 & 3. Heavy rainfall will cause greater leaching and runoff. Sandy soil would have a higher leaching potential than clay soil due to larger pore spaces and lower CEC [52] [48]. Higher humidity enhances soil microflora proliferation. Similarly, the persistence of herbicides in dry soil is greater as compared in wet soil. The ultimate fate of herbicide in soil depends on the number of processes such as volatilization, leaching, runoff, and degradation by microbes, chemical processes, and photodecomposition. Herbicide families that have persistent members include the triazines, uracils, phenylureas, sulfonylureas, dinitroanilines, isoxazolidinones, imidazolinones, and certain plant growth regulators belonging to the pyridine family ([8]. Pendimethalin at a lower rate (0.5 kg ha^{-1}) gave the maximum persistence in soil compared to trifluralin and fluchloralin. This might be because pendimethalin is relatively less volatile (vapour pressure: 3 × 10-5 at 25°C) than trifluralin and fluchloralin [40]. Pendimethalin was more persistent when incorporated in the soil than applied to the soil surface [61].

Table2: Persistence of some herbicides used in berseem crop

Herbicide	Persistence in soil (days)	Source
Butachlor	100	[53]
Fluchloralin,	Up to 243	[63]
Imazethapyr	90-240	[31] [47] [49]
Oxyflourfen	60-80	[10]
Pendimethalin	60-200	[64] [29] [11] [33] [49] [50]

Table3: Half-lives of some herbicides used in berseem crop

S.No.	Herbicide	Half-lives (Days)
1	Butachlor	5-24
2	Fluchloralin,	12-46
3	Imazethapyr	57-71
4	Oxyflourfen	12-29
5	Pendimethalin	55-77

Source: [51]

Effect of herbicides on soil environment

Soils contain microorganisms viz. bacteria, fungi, yeasts, photosynthetic organisms including algae and microorganisms such as protozoa, nematodes, mites, springtails, spiders, insects and earthworms. The functions of this complex array of biota are diverse and include residue decomposition, nutrient storage and release, soil structure and stability, resistance against disease and degradation or immobilization of soil pollutants. Weed control in agricultural and non-agricultural lands is rapidly shifting towards chemical methods because of its time, labor and cost advantages. The influence of herbicides on soil biota population and agriculturally important soil bio-chemical processes are given in Table 4.

Effect of herbicide on economic

In the silty clay loam soil of Pantnagar, [1] reported that maximum gross return (44592 Rs./ha), net return (31161 Rs./ha) and benefit: cost ratio (2.32) were due to oxyfluorfen @ 0.10Kg/ha + imazethapyr @0.15 kg/ha (Immediately after 1st cut) *fb* imazethapyr @ 0.15 kg/ha (After 1st and 2nd cut) and weed free. At Rahuri, [24] observed that pre-emergence application of oxyflororfen @ 0.100 kg a.i./ha *fb* imazethapyr @ 0.100 kg a.i./ha as post-emergence registered significantly the highest gross monitory (1,11,866 Rs./ha), net monitory (54,810 Rs./ha) and B:C ratio (1.96) than rest of treatments followed by imazethapyr @ 0.100 kg a.i./ha applied immediately after harvest of 1st and 2nd cut (Gross monitory 1,01,402 Rs./ha, net monitory 47,523 /Rs.ha and B:C ratio 1.88). Similarly, [16] at Pune, Maharashtra noticed that pre-emergence application of oxyflourfen 0.10 kg/ha *fb* post-emergence application of imazethapyr 0.10 kg/ha immediately after harvest of 1st cut recorded maximum gross monetary returns (1,89,313 Rs./ha) net monetary returns (1,34,048 Rs./ha) and B:C ratio (3.43) compared to rest of the treatments. However, [44] the experiment laid out at Rahuri, Maharashtra and reported that the maximum mean gross returns (96,520 Rs./ha), net returns of (48,970 Rs./ha) and B:C ratio (2.09) was recorded due to application of imazethapyr 0.1 kg/ha after 1st and 2nd cut. Furthermore, [62] at Jhansi, the highest net returns (59,336 Rs./ha) as well as benefit-cost ratio (2.35) were recorded under post-emergence application of imazethapyr @ 0.1 kg a.i./ha. At Gurdaspur, [6] revealed that the application of fluchloralin 0.45 kg/ha *fb* imazethapyr 0.075 kg/ha resulted in attaining maximum net returns (1,98,856 Rs./ha) and benefit: cost ratio (2.89) over all other weed control methods which was closely followed by oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.075 kg/ha for obtaining net returns (1,95,151 Rs./ha) and benefit:cost ratio (2.83). [18] at Ranchi, Jharkhand observed that pre-emergence application of pendimethalin @ 0.4 kg a.i/ ha caused significantly higher maximum gross return (1,92,903 Rs. /ha), net return (1,69,191 Rs. /ha) with B:C ratio (7.12) over other herbicidal combinations.

Conclusion

Weed control in berseem by chemicals is an important method in areas where labor is scarce and costly. It provides greater flexibility, and lesser labor costs, makes management of labor easy, and notably decreases the risk of mishaps by plummeting exhaustion and workers' exposure to sharp implements and power equipment. Some of the chemicals either alone or their combinations at lower doses have been proven an economically viable alternative to hand weeding in the management of weeds in berseem fields. Based on weed dynamics, weed ecology, weed control efficiency and earlier work done by many workers it can be concluded that a combination of oxyfluorfen with imazethapyr is more sustainable and economical for controlling the weeds in the berseem crop.

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Conflict of Interest

All the authors declare that they have no conflict of interest**.**

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