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Comparative Efficacy of Chemical and Plant based Herbicides on Weed Management in Winter Sown Ashwagandha Crop [*Withania somnifera* (L.) Dunal]

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ABSTRACT: *Withania somnifera* (L.) Dunal is a valuable and prominent medicinal plant species cultivated in India. Weed infestation is one of the major problems affecting growth and productivity of this crop. Experiments were conducted at Herbal Garden, Department of Plant Physiology, JNKVV, Jabalpur, India during winter seasons of 2020-21 and 2021-22 to find out suitable herbicide(s) out of chemical and plant based herbicides. Results revealed that single post-emergence spray of chemical herbicides viz. Quizalofop-p-ethyl@ 50 g ha^{-1}, Clodinofop-p-propargyl @ 60 g ha^{-1} and Haloxyfop r-methyl @ 750 g ha^{-1} individually were very effective in controlling weeds without any serious effect on Ashwagandha crop. These herbicides controlled mainly monocot weeds. Plant based organic herbicide (alcoholic extract Withania root @10 kg ha^{-1}) and chemical herbicide (Oxyflourfen @100 kg ha^{-1}) individually effectively controlled weeds specially dicot weeds with some adverse effects on growth and survival of Withania crops. Quizalofop-p-ethyl prolonged vegetative and reproductive phases. One spray of Quizalofop-p-ethyl 30 days after planting not only effectively manages weed population in Withania crop but also realized maximum dried root yield (1077 kg ha^{-1}), leaf yield (1666.33 kg ha^{-1}), seed yield (788.33 kg ha^{-1}), and total plant biomass yield (5440.67 kg ha^{-1}). Withania root extract was equite effective in controlling both monocot and dicot weeds but less effective than chemical herbicide Quizalofop-p-ethyl because it realized less dried root yield (632.67 kg ha^{-1}). Withania root extract was very effective in maximizing harvest index (22.52%) taking root as economic yield showing improvement in partitioning of assimilates towards economic sink, i.e. root.

Keywords: *Withania somnifera,* medicinal plants, chemical control, Quizalofop, Haloxyfop, Clodinofop, Oxyflorfen.

INTRODUCTION

Ashwagandha/Wintercherry (*Withania somnifera*) is one of the major medicinal crops cultivated in many parts of India (Singh *et al.,* 2011; Tripathi *et al.,* 2012). It belongs to family Solanaceae. Whole plant is used medicinally for curing many diseases of human beings, but root and leaves are major parts used commercially. Leaf has anti-inflammatory, anti-hepatoxic and antibacterial properties (Tiwari *et al.,* 2014; Afewerky *et al.*, 2021). It possesses anti-tumor, hypotensive brad cardiac and respiratory stimulant activities. Ashwagandha has antibacterial, anti-tumor, anti-arthritic immunosuppressive nature (Kushwaha *et al.,* 2012; Mahima *et al.,* 2012). It is a native of Mediterranean region it occurs naturally in arid and semi-arid parts of India (Bhaure *et al.,* 2012; Jhankare *et al.,* 2013). It is a cultivated all over north west and central parts of the India as rainfed crop. Cultivation is mainly done in Madhya Pradesh in about 2000 hectares (Bhaure *et al.,* 2014; Jana and Charan 2018). *Withania* is generally cultivated as late rainy and winter season crop. It is initially slow growing crop during initial stage; hence it is badly affected due to competition from fast growing weeds. In absence of proper weed management, crop growth and productivity is affected seriously to the tune of complete crop failure.

Hand weeding is one of the most effective weed control measures but the non-availability of laborers and high cost involved therein, hinder the timely removal of weeds (Hendawy *et al.*, 2020). In order to mitigate the problem due to weeds, a suitable, easy and cost-effective weed management strategy using chemical herbicides and botanicals is needed. Kulmi and Tiwari (2005) compared hand weeding and combination of single hand weeding with pre-emergence application of herbicides (isoproturon/ glyphosate) on weed management of *Withania* crop and reported superiority of three hand weeding over combination of herbicide and single hand weeding. Although a lot of work is reported in many crop on efficacy of herbicides in managing weeds (Carrubba and Militello 2013; Carrubba, 2017; Hendawy *et al.,* 2020), but practically

no work reported on chemical/botanical weed management in *Withania somnifera* crop so far. Hence, the present research study was undertaken to find out suitable chemical/botanical herbicides to manage weeds in *Withania* crop.

MATERIALS AND METHODS

The experiments were conducted during the winter seasons of 2020-21 and 2021-22 at the Herbal Garden, Department of Plant Physiology, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, India. The study site comes under the subtropical region with average rainfall of 1386 mm and evaporation of 1502 mm. Soil was low in organic carbon with clay loam texture. The Field was properly ploughed, pulverized and leveled properly and plots were prepared according to layout plan. The experiments were conducted in Randomized Block Design and replicated thrice. Gross plot size was 1.8 m × 3.0 m. Pre-germinated 30 days old *Withania* seedlings (variety: Jawahar Asgandh 20) were transplanted in the field. Nine treatments of weeds management strategy (*i.e.* seven different chemical herbicides spray along with one spray of *Withania* root extract and one control having no application of herbicide or hand weeding) were tested for efficacy against weeds in *Withania* crop as per the details given in Table 1.

Table 1: Details of treatments and doses of chemical and plant based herbicides used under the study.

Treatment	Details of spray treatment	Dose
T_1	Control	Water spray
T_2	Oxyflourfen	100 g ha^{-1}
T_3	Metribuzin	525 g ha^{-1}
T_4	Quizalofop-p-ethyl	50 g ha^{-1}
T_5	Clodinofoppropargyl	60 g ha^{-1}
T_6	Chloromuron ethyl	15 g ha^{-1}
T_7	Pendimethalin	1000 g ha^{-1}
T_8	Haloxyfopr.methyl	750 g ha^{-1}
T_9	*Withania* root extract (alcoholic)	Alcoholic extract of 10 kg *Withania* roots ha^{-1}

Spray of treatments as per schedule were done 20 days after planting *Withania* crop in the field. *Withania* extract were prepared as per following procedure. 100 g of grinded *Withania* roots were taken macerated in 500 ml ethanol for 24 hours. Extract was decanted and mixed with 250 ml of water before spraying. The observations were recorded on diversity and number of weeds before and after treatment along with survival percent of *Withania* crop. Yield attributes and yield data were also recorded during both years. Average of both the years was analyzed statistically as per methods proposed by Fisher (1967).

RESULTS AND DISCUSSION

Weeds are major constraints in establishment of seedling growth, development and productivity of agriculture and horticulture crop all over the world (Tripathi, 2017). Productivity of crop is seriously affected if weeds are not managed properly particularly during initial stages of seedling establishment (Mishra *et al.,* 2022). They compete with crop for space, nutrients and water. They also release some allele-chemicals which hinders seed germination and crop establishment (Kong *et al.,* 2019; Chaudhary *et al*., 2022). *Kharif* and late *Kharif* crop are more prone to weed invasion due to ample availability of moisture and temperature suitable for their growth.

Ashwagandha crop is sown mainly as late-rainy and winter-season crop in India (Rajeswara Rao, 2012) particularly in Madhya Pradesh. Since this crop grows slowly during initial stages, it is much prone to weed invasion. If proper weed management strategy is not applied it may result into complete failure of crop. Present experiments were conducted to find out suitable chemical / botanical herbicide as an alternative to expensive manual weeding for proper weed management in *Withania somnifera.*

Diversity and population of weeds before treatment. Results revealed (Table 2) that there were 12 species of weeds found in *Withania somnifera* crop. These species were Wild rice (*Oryza fatua)*, Senji (*Melilotus indica*), Dhoob grass (*Cynodon dactylon*), *Sonchus asper*, Carrot grass (*Parthenium hysterophorus*), Krishanneel (*Anagallis arvensis*), Billygoat-weed (*Ageratum conyzoides*), Wild onion (*Asphodelus tenuifolius*), Berseem (*Trifolium alexandrinum*), Bathua (*Chenopodium album*), Makoi (*Solanum nigrum*) and Motha (*Cyperus rotundus*). Four weed species (Wild rice, Cynodon, Asphodelus and Cyperus) are monocotyledons while others are dicotyledons in nature. Out of these weeds wild rice is the dominant weed (average number 679 per plot), followed by senji (average number 45.78 per plot),wild onion (average number 16.70 per plot), *Ageratum conyzoides* (average number 16.22 per plot), motha (average number 14.78 per plot), Sonchusasper (average number 6.85 per plot), Berseem (average number 4.22 per plot), Dhoob grass (average number 3.78 per plot), *Solanum nigrum* (average number 3.15 per plot), Parthenium (average number 2.96 per plot) and Bathua (average number 2.63 per plot). Krishan neel recorded the minimum weed population (average number 1.52 per plot) in winter sown *Withania* crop.

Table 2: Diversity and population of weeds per plot before herbicides/ botanicals spray.

Plot No.	*Wild rice*	*Melilotus indicus*	*Cynodon dactylon*	*Sonchus asper*	*Parthenium* spp.	*Anagallis arvensis*	*Ageratum conyzoides*	*wild onion*	*Berseem*	*Chenopodium album*	*Solanum nigrum*	*Cyperus rotundus*
1	782	52	4	4	5	6	27	42	5	12	5	15
2	756	6	8	2	0	4	12	15	2	4	2	16
3	765	8	6	3	2	0	24	8	2	0	2	12
4	758	37	0	3	4	0	22	20	4	0	2	12
5	743	75	0	5	4	0	16	18	3	0	1	22
6	783	40	2	12	0	2	8	14	3	0	3	5
7	752	36	13	9	0	0	13	15	2	0	0	28
8	628	19	0	3	2	3	5	5	3	9	4	12
9	596	25	3	6	4	2	12	3	2	2	2	4
10	664	20	5	8	8	2	9	6	3	3	2	8
11	608	28	0	4	3	2	7	3	6	7	7	12
12	685	35	10	8	0	0	11	18	8	0	0	24
13	690	42	2	12	0	3	11	20	4	0	6	12
14	450	85	0	8	8	0	10	28	4	0	4	14
15	458	38	0	6	5	0	29	20	12	0	2	15
16	748	8	3	4	4	0	20	10	4	0	3	18
17	610	12	6	5	0	3	8	17	3	5	3	14
18	760	48	6	12	7	3	35	48	8	9	6	20
19	722	35	1	10	0	4	6	22	2	0	3	10
20	720	48	0	8	5	0	16	16	4	0	3	15
21	615	35	0	6	3	0	33	24	8	0	5	8
22	768	40	3	8	0	0	28	12	3	0	3	20
23	508	58	3	5	0	1	10	18	2	7	1	21
24	745	54	8	8	6	3	40	28	6	7	8	21
25	686	182	13	14	0	0	8	16	6	0	0	15
26	694	45	6	4	6	2	13	3	3	3	3	12
27	632	40	0	8	4	1	5	2	2	3	5	14
Total	**18326**	**1151**	**102**	**185**	**80**	**41**	**438**	**451**	**114**	**71**	**85**	**399**
Average	**679**	**42.63**	**3.78**	**6.85**	**2.96**	**1.52**	**16.22**	**16.70**	**4.22**	**2.63**	**3.15**	**14.78**

Diversity and population of weeds after herbicides/ botanicals spray. After 20 Days of application of herbicides/ botanicals spray, diversity and population density of weeds were differentially affected as compared to initial diversity and density (Table 3). Quizalofop-p-ethyl, Clodinofop propargyl and Haloxyfop- r- methyl were found very effective in complete killing of wild rice without any significant negative effect on Withania crop. Withania root extract spray (as botanical herbicide) was also effective in lowering population of Wild rice effectively from 679 to 95 per plot in comparison to population in plot without any spray (control). Wild rice population was effectively managed to practically zero using Quizolofop-p ethyl, Clodinofop-p-propargyl and Haloxyfop r-methyl. Other herbicides also reduce population of wild rice, but to lesser extent except Oxyflourfen. The highest dominance of this weed in the field was found when no application herbicide or any weed management practice was applied. Since Quizolofop-p ethyl, Clodinofop propargyl and Haloxyfop r-methyl selectively kills most of the monocot and grassy weeds and few dicot weeds. Hence, they are most effective in controlling wild rice. All three post-emergence herbicides metioned above are ACCase (Acetyl CoA Carboxylase) inhibitors. This is a key enzyme catalyses the carboxylation of acetyl-CoA to produce Malonyl-CoA, which in turn is utilized by fatty acid synthase (FASN) to form long-chain saturated fatty acid in Chloroplast and other plastids. They finally used to form membrane lipids. Most of the broadleaf species are naturally resistant to these type of herbicides owing presence of a less sensitive ACCase enzyme in them (Shariq *et al.,* 2015).

Spray of both of Metribuzin and Chloromuron ethyl individually were effective in controlling/ killing *Melilotus* compared to all other weed control chemicals/ botanicals. Metribuzin was quite suitable post emergence broad spectrum weedicide for controlling both narrow and broad leaved species. On the other hand Chloromuron ethyl is selective post emergence weedicide for dicots and nets edges. *Melilotus indica* is a broad leaved weed and these two herbicides has specific selectively for this weed. Oxyflourfen, Haloxyfop- r-methyl and Withania root extract were also found effective but did not kill the weed completely rather than decreasing population to some extent. Quizolofop-p ethyl and Clodinofop-p-propargyl were not found effective at all against *Melilotus.*

Quizalofop-p-ethyl, Clodinofop propargyl, Pendimethalin and Haloxyfop- r-methyl were very effective in killing *Cynodon dactylon* completely without less deleterious effect on *Withania somnifera*. Withania root extract spray also effectively reduced *Cynodon* population which very aggressive weed and difficult to control. This is all new finding as botanical herbicide (alcoholic extract of Withania somnifera roots) against *Cynodon.* Cynodon dactylon (a grassy weed) was completely controlled using Quizolofop-p ethyl, Clodinofop-p-propargyl, Pendimethalin and Haloxyfop r-methyl. These herbicides are effective in controlling monocot weeds, hence they also found effective in controlling *Cynodon dactylon.*

Population of Sonchus asper was completely killed by spray of Weedicides like as Oxyflourfen, metribuzin and chloromuron ethyl but these herbicide particularly metribuzin and chloromuron completely kills the main crop of Withania. Oxyflorfen is non–sytemic broad-spectrum herbicide used as pre- or post –emergence application for killing both narrow and broad – leaved weeds. It controls weeds by inhibiting an essential enzyme known as protoporphyrinogen oxidase leads to disruption of cell membranes in presence of light and thereby plant death (Shariq *et al.,* 2015). Pendimethelin, Quizalofop were also effectively controlled this weed without damaging *Withania* crop. Sonchus asper (a broad leaf weed) was controlled completely by applying Oxyflourfen, Metribuzin and Chloromuron ethyl. These results were due to selective killing of broad-leaved weeds by above herbicides.

Oxyflourfen, Metribuzin, Chloromuron and Pendimethelin were equally effective in completely killing weed population of *Parthenium* but Metribuzin and Chloromuron have detrimental effect on Ashwagandh crop also. Hence were not suitable for weed control in *Withania.* Pendimethaln was appropriate for killing Parthenium hysterophorus (a broad leaf weed) in *Withania* crop. Pendimethalin is selective post and pre- emergence herbicide to control annual grasses and certain broad- leaved weeds. It inhibits cell division and cell elongation in sensitive plants by disrupting micro-tubular activity during cell division and retard growth and plant death (Shariq *et al.,* 2015). *Parthenium hysterophorus* was effectively controlled by Oxyflourfen, Metribuzin, Chloromuron and Pendimethalin to the extent of zero population. All these are very effective in controlling broad leaved weeds as compared to narrow leaved one.

Population of Krishanneel *(Anagallis arvensis*) was controlled significantly with spray of all chemical weedicides. *Anagallis arvensis* (broad-leaved weeds) found in Withania crop was controlled effectively by almost all herbicides except Haloxyfop r-methyl and Withania root extract. This weed was sensitive to both types of herbicides.

Pendimethelen was found very effective for control of *Ageratum conyzoides* without damaging ashwaghandha crop. Oxyflourfen, Metribuzin and Chloromuron were similarly effective in controlling *ageratum* conyzoides, a potent broad-leaved weed of *rabi* season crop.

Haloxyfopr methyl and *Withania* root extract were equally effective in *Asphodelus tenuifolius* least harm full effect on main crop i.e., *Withaina somnifera*. Wild onion population was not management by most of the herbicides. Only Haloxyfop (synthetic herbicide) and Withania root extract were very effective in controlling wild onion. Wild onion germinates late in Withania field in winter, which may effectively be controlled by various alkaloids present in root extract of *Withania somnifera* (L.) Dunal. Seeds of wild onion may force to dormancy due to antagonistic effect of Haloxyfop and Withania root extract.

Pendimathelin and *Withania* root extract were found to be based alternatives for controlling *Trifolium alexandrinum* weed in Ashwagdha crop. Selective broad-leaved weed killer like Metribuzin, Chloromuron and Pendimethalin were effective in controlling Berseem (*Trifolium alexandrinum.*) This may be due to selectivity of herbicides to this weed than other herbicides under the study.

Quizalofop-p-ethyl and Clodinofoppropargyl were very effective chemical herbicides *Chenopodium album* weed population in *Withania* crop. *Withaina* root extract spray was also effective lowering *Chenopodium* population and hence effective botanical weedicide for the purpose. In a similar study, Sharma *et al.* (2017) also used root extract of *Withaina* against *Chenopodium* and found effective in the management of this weed species. Metribuzin, Quizalofop-p-ethyl, Clodinofoppropargyl, Chloromuron ethyl and Pendimethalin were found effective in killing *Chenopodium album* completely with Withania crop as compared to no weeding/weedicide application. Singh *et al.* (2018) also reported the use of Metribuzin to control broadleaf weeds in potato crop.

Quizalofop and *Withania* root extract were found as effective alternative for controlling *Solanum nigrum* as weed in *Withania* crop although other herbicides like metribuzine chloromuron completely killed these weed but they were also have very lethal for *Withania* crop. Hence they cannot be recommended for controlling weeds associated *Withaina* crop under winter sown condition. *Solanum nigrum* was very effectively managed using Metribuzin, Chloromuron ethyl and Pendimethalin against all other weedicide and weed management strategy. All these herbicides selectively kill the broad-leaved weeds.

For controlling *Motha* (*Cyperus rotundus*) associated weed of *Withania somnifera* crop pendimethelin was best alternative followed by spry of *Withania* root extract as botanical herbicide. *Cyperus rotundus* is very harmful weed in *Withania* as it competes with Ashwagandha root for nutrient and moisture. It also damages the quality of root as it penetrates the soft root of *Withania* crop. Chloromuron ethyl and Pendimethalin were equally effective in controlling these weeds. The selectively of Pendimethalin to sedges like *Cyperus rotundus* is well established in other crops by various scientist.

Effect of herbicides/ botanicals on survival of crop (*Withania somnifera*). Survival of Ashwagandha (*Withania somnifera* (L.) Dunal.) was affected significantly with spray of weedicides (Table 3). The maximum survival of *Withania* crop was found with Quizalofop followed by Haloxyfop, Clodinofop, Pendimethalin, Withania root extract and Oxyflourfen. Treatment with no weeding and chemical spray resulted in complete mortality of *Withania* crop as result of heavy weed population of dicot and monocot weeds. Weed management in Ashwagandha crop so important that in absence of weed management, total crop failure occurred. In present experiment without any chemical, biochemical weed control, no *Withania* crop was survived *Chenopodium album* after 50 days of sowing. This is due to the fact that *Withania* grows slowly during early stages of growth and plant cannot get their light, nutrient and water requirement due to tough competition posed by weeds. Out of all herbicide quizalofop-p-ethyl was effective weed control without

any serious effect on *Withania* crop. Clodinofop-p-propargyl and Haloxyfop r-methyl were also did not kill *Withania* crop. They kill only weeds of different nature. After these three weedicides, spray of root extract of *Withania somnifera* (L.) Dunal is effective in suppressing weed growth with no harmful effect on *Withania* crop survival. On the other hand, metribuzin and Chloromuron ethyl completely killed Withania along with broad leaved weeds in the crop field.

Effect of chemical and plant-based herbicides on estimated biomass yield and harvest index of *Withania somnifera* crop. Yield in terms of biomass partitioned into leaf, stem, seed and roots and its comparative accumulation into economic sinks (HI) were major attributes of productivity. Root and leaf are the main economic part of Ashwagandha crop used medicinally.

Estimated yield (kg ha^{-1}) of leaf, stem, root and total biomass was found maximum when sprayed with Quizalofop-p-ethyl, Clodinofop propargyl and Haloxyfop r-methyl. The maximum root yield of 1077 kg ha^{-1} was achieved with Quizalofop-p-ethyl spray which was similar statically with spray of two herbicide Clodinofop propargyl and Haloxyfop- r-methyl in realization of the maximum root yield (Table 4).

Harvest index (%) is the percentage of economic yield the total biomass. When seed was taken as economic yield the maximum hi (23.71%) was found with spray of Withania root extract. On the other hand when root was taken as economic yield portion, the maximum Harvest index 22.52% was again found with spray of *Withania* root extract. This is a remarkable result that although root yield was maximum with quizalofop-p-ethyl, Clodinofop propargyl and Haloxyfop r-methyl, but relative partitioning of total photo assimilates toward roots and seed was lesser as compared to when *Withania* root extract was sprayed. Hence, *Withania* root extract not only useful in increasing root yield by suppressing weeds but also increasing the partitioning efficacy of assimilates toward economic sink (root and seed). Although root yield per ha was found maximum with the spray of herbicide Quizalofop-p-ethyl.

Table 3: Effect of chemical and plant based herbicides on diversity and population of weeds in *Withania* crop.

	Population density (No. of plant per plot)												
Treatments	***Wild Rice***	***Melilotus indicus***	***Cynodon dactylon***	***Sonchus asper***	***Parthenium* spp.**	***Anagallis arvensis***	***Ageratum conyzoides***	***Wild onion***	***Trifoliumalexandrinum***	***Chenopodium album***	***Solanum nigrum***	***Cyperus rotundus***	***Withania* Survival %**
T1 Control	764.3	51.3	4.0	7.3	6.0	4.0	34.0	39.7	6.3	9.3	6.3	17.7	0.0
T2 Oxyflourfen	624.7	7.3	8.0	0.0	0.0	0.0	0.0	16.7	2.3	5.3	1.7	17.0	14.7
T3 Metribuzin	110.0	0.0	6.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	16.7	0.0
T4 Quizalofop-p-ethyl	0.0	36.7	0.0	2.7	4.0	0.0	28.0	16.7	5.7	0.0	3.0	11.7	145.0
T5 Clodinofoppropargyl	0.0	50.7	0.0	5.0	5.7	0.0	14.0	20.7	3.7	0.0	3.3	16.0	136.3
T6 Chloromuron ethyl	125.0	0.0	2.0	0.0	0.0	0.0	0.0	18.7	0.0	0.0	0.0	0.0	0.0
T7 Pendimethalin	141.3	37.7	0.0	2.3	0.0	0.0	3.3	3.3	0.0	0.0	0.0	0.0	58.0
T8 Haloxyfopr.methyl	0.0	29.0	0.0	4.7	3.0	1.7	5.7	0.0	3.0	5.0	5.3	12.7	139.3
T9 *Withania* extract	95.7	26.7	3.0	5.3	5.7	1.7	11.3	0.0	2.3	2.7	2.3	8.0	33.3
SEm (±)	**0.3**	**0.2**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.2**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
LSD (0.05)	**0.9**	**0.6**	**0.3**	**0.4**	**0.2**	**0.2**	**0.4**	**0.4**	**0.2**	**0.2**	**0.2**	**0.4**	**0.3**

Table 4: Effect of chemical and plant based herbicides on estimated biomass yield and HI (%) of *Withania somnifera* crop.

Treatment	Stem biomss (kg ha^{-1})	Leaf biomss (kg ha^{-1})	Root biomss (kg ha^{-1})	Seed yield (kg ha^{-1})	Total plant biomss (kg ha^{-1})	Harvest index (Seed)	Harvest index (Root)
T1- Control	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
T2-Oxyflourfen	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
T3-Metribuzin	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
T4-Quizalofop-p-ethyl	1910.33 (43.67)	1666.33 (40.71)	1077.00 (40.71)	788.33 (28.06)	5440.67 (73.76)	14.48	19.79
T5-Clodinofoppropargyl	1777.00 (42.16)	1644.00 (40.54)	728.33 (40.54)	781.33 (28.06)	4929.67 (70.22)	15.84	14.77
T6-Chloromuron ethyl	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
T7-Pendimethalin	1043.67 (32.27)	943.67 (30.70)	332.67 (30.70)	699.33 (26.42)	3020.00 (54.96)	23.14	11.01
T8-Haloxyfopr.methyl	1688.33 (41.07)	1555.00 (39.44)	643.67 (39.44)	777.00 (27.86)	4663.33 (68.29)	16.67	13.80
T9-*Withania* extract	755.00 (27.45)	754.67 (27.46)	632.67 (27.46)	666.00 (25.73)	2808.33 (53.00)	23.71	22.52
SEm (±)	**0.50**	**0.55**	**0.59**	**0.49**	**0.17**	**0.07**	**0.08**
LSD (0.05)	**1.47**	**1.63**	**2.05**	**1.45**	**0.49**	**0.19**	**0.24**

CONCLUSIONS

Withania root extract was quite effective in controlling both monocot and dicot weeds but less effective than chemical herbicide Quizalofop-p-ethyl because it realized less dried root yield (632.67 kg ha^{-1}). Withania root extract was very effective in maximizing harvest index (22.52%) taking root as economic yield showing improvement in partitioning of assimilates towards economic sink, *i.e.,* root.

Author contributions: SM, AR and GT Conceived and designed the analysis; SM Collected the data; RSR, RKS and NT Contributed data or analysis tools; RSR and GT Performed the analysis; SM,GT and NT Wrote the paper.

Conflict of Interest. None.

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