Journal homepage: https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)

Effect of weed and nitrogen management practices on controlling weeds and enhancing the productivity of linseed (*Linum usitatissimum* L.) under utera conditions

Narinderpal Singh
Block Agriculture Office, Dhuri, Distt.- Sangrur, Punjab
Pankaj Chopra ✉
Department of Agronomy, CSK HPKV, HAREC- Kukumseri, L&S, H.P.
Suresh Kumar
Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, H.P.
Gurpreet Singh
Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, H.P.
Navneet Kaur
Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, H.P.

ARTICLE INFO

Received : 26 July 2023
Revised : 21 November 2023
Accepted : 04 January 2024

Available online: 25 February 2024

Key Words:
Dehydrogenase activity
Linseed
Nutrient uptake
Quality
Seed yield
Weed control

ABSTRACT

A field experiment was executed during the *Rabi* season at CSKHPKV, Palampur, to evaluate the effects of different weed control and nitrogen management practices on weed control, yield, nutrient content, dehydrogenase activity and the oil content of linseed. The experiment was set up in the RBD with 3 replicates consisting of fifteen treatment combinations comprising five weed controls (*viz.* isoproturon 1.25 kg/ha, clodinafop propargyl + metsulfuron methyl 60+4 g/ha, clodinafop propargyl + carfentrazone ethyl 60+10 g/ha, hand weeding twice and weedy check) and three nitrogen levels (*i.e.,* FYM 5 t/ha, 75 and 100% RDN). The soil texture at the experimental site was silty clay loam, acidic and medium in available nitrogen, phosphorus and potassium. The results showed that the use of clodinafop propargyl + metsulfuron methyl 60+4 g/ha significantly decreased the count and dry matter content of the total weeds at the maximum count and dry matter stage. However, 1.25 kg/ha isoproturon was likewise effective at significantly reducing the total weed count and was the next best at reducing the dry matter content of the total weeds. The effective control of weeds by the application of isoproturon at 1.25 kg/ha (Post.) significantly increased plant growth without any toxicity, which contributed to increased nutrient uptake and increased seed, straw and oil yields in the linseed treatment. Among the nitrogen levels, a considerably lower count and dry matter content of the total weeds were recorded in the 100% RDN plots, followed by the 75% RDN treatment. The application of 100% RDN resulted in significantly greater NPK uptake than did the other treatments, which contributed to considerably greater seed, straw and oil yields. Thus, the application of isoproturon at 1.25 kg/ha (Post.) with 100% RDN was proven to be the most effective at realizing higher seed and oil yields with better weed control in linseed plants grown under utera conditions.

Introduction

Linseed (*Linum usitatissimum* L.) is an important winter (rabi) oilseed crop following the rapeseed mustard of India and is generally cultivated under rainfed and utera systems. It is a food and fiber crop cultivated in cooler regions of the world. Linseed is the best herbal source of omega-3 fatty acid (linolenic acid) and lignan, which have significant nutritional and medicinal effects on the human body

Corresponding author E-mail: pankuch@rediffmail.com
Doi: https://doi.org/10.36953/ECJ.24602691

according to recent medical research findings (Touré and Xueming 2010). Additionally, soluble and insoluble fiber, complete carbohydrates, proteins, vitamins, and minerals are present in high concentrations in edible linseed oil that is utilized for human consumption (Genser and Morris, 2003). The oil content of seeds generally varies from 33-45%. India contributes 10.81% of the world's area and 5.30% of the world's linseed production. With an average production rate of 574 kg/ha, 1.72 lakh ha of linseed are grown in India, producing 0.99 lakh tons (Anonymous, 2019). Generally, the maximum area covered by this crop falls under a system in which linseed seeds are broadcasted on a standing paddy crop, *i.e.,* 15-20 days before harvesting the paddy crop. This system, called the *utera* or *paira* system of cultivation, is noteworthy for its limitations on the use of modern, advanced technology. This practice, however, saves time and money and acts as the best natural resource conservation system; however, low plant population size due to poor weed control, little or no use of nutrients, growth on residual inputs, incidence of insects and pests and use of local/desi seeds are the major constraints that limit plant productivity. Weed competition in this system is one of the important limitations for low productivity of the crop because the available field conditions after paddy harvest without tillage favor the infestation of grassy and broadleaved weeds. Any possibility left under such a situation is to minimize crop-weed competition. This necessitates the use of appropriate herbicides (after emergence) to manage complex weed flora. Additionally, it is preferable to include this strength by combining two herbicides into one complementing mixture for broader-spectrum weed control, and this combination needs to be tested on this crop, as it is for other crops where positive results with respect to weed control have been achieved. Linseed productivity suffers due to poor nutrient inputs, in which nitrogen plays an important role. Even though nitrogen has a significant impact on the growth, development, and yield of crops, this impact is significantly influenced by changes in environmental factors, moisture availability, source, method, and amount of fertilizer added, particularly in the utera system where the presence of previous crop residues plays a key role. In this respect, under such a system, fertilization is the most important crop management technique and is known to affect seed yield (Dordas 2010; Meena *et al.,* 2011). Hence, the use of an optimum nitrogen dose may be helpful for increasing the productivity of linseed crops. The yield of linseed can increase by more than 100% over the prevailing management practices under utera conditions combined with fertilizer, weed control and plant management (Kumar *et al.,* 2015). Hence, to maximize the potential of linseed, a study was performed to evaluate the effects of weed control and nitrogen management on the yield and nutrient uptake of linseed.

Material and Methods

Field experiments to assess the effects of different herbicides applied alone or in combination with nitrogen levels and two crucial agronomic management practices for weed control, yield and quality of linseed were performed at the Main Experimental Farm of the Department of Crop Improvement, Chaudhary Sarvan Kumar Himachal Pradesh Krishi Vishvavidyalya, Palampur (H.P.) during *Rabi* 2015-16, as the slow initial growth of these plants during winters up to mid-February makes these plants more vulnerable to weed infestation, which requires proper attention to obtain the expected plant growth and yield. Moreover, a proper supply of nitrogenous fertilizers is needed because it affects growth and development throughout the life span of the crop and results in improved nutrient uptake, photosynthesis and thereby crop yield. The experimental site was located at 32°6' N, 76°3' E, with an elevation of 1290.8 meter above mean sea level in the north-western Himalayas. Agro-climatically, the experiment location is located in Himachal Pradesh's sub-temperate humid zone, which is known for its chilly winters and moderate summers as well as its heavy monsoon precipitation. In general, the annual rainfall ranges between 1500 and 2500 mm, of which a major part is received during June to September (approximately 80%), and the remaining rainfall occurs during the winter months. The data recorded at the meteorological observatory of the Department of Agronomy, College of Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, revealed that the total rainfall received during the crop period (4th Oct., 2015, to 20th April 2016) was 297.2 mm. The mean maximum temperature for the crop season varied from 14.4 to

30.0 °C, and the minimum temperature ranged from 1.8 to 16.0 °C. The mean relative humidity remained between 42.8 and 76.6% during the crop season. The experiment consisted of fifteen treatments comprising five weed control agents (*viz.* isoproturon (1.25 kg/ha), clodinafop propargyl + metsulfuron methyl 60+4 g/ha, clodinafop propargyl + carfentrazone ethyl 60+10 g/ha, hand weeding twice and weedy check) and three nitrogen levels {*i.e.*, FYM 5t/ha (Farmer's practice), 75 and 100% RDN} were tested in a randomized block design with three replications. To record the weed count and dry weight of the total weeds, a 50 cm × 50 cm quadrat was positioned randomly at two points in each plot. The total weed count and dry weight were noted at the maximum count and dry matter stage, *i.e.,* 120 DAS. To record the total weed dry weight, the samples of total weeds were oven dried at a temperature of 70 °C until a constant weight was reached. The count and dry matter of the total weeds that were accordingly noted were averaged, and the results were multiplied by a factor of 4 to obtain the number per square meter. Weed control efficiency was calculated based on weed dry weight according to the formula given by Mishra and Tosh (1979).

$$\textbf{Weed Control Efficiency (\%)} = \frac{Wc - Wt}{Wc} x\ 100$$

where

Wc = Weed dry weight (g/m^2) in the control plot and

Wt = Weed dry weight (g/m^2) in the treated plot

The stalks harvested along with the capsules from each net plot were threshed gently by beating with wooden rollers at maturity. The seed yield was expressed in kg/ha by multiplying the net plot yield by a factor of 1666.67. After the plants were threshed, the stalks were sun-dried and weighed. The recorded weight was expressed in kg/ha by multiplying the net plot yield by a factor of 1666.67, as the net plot size was 3 m × 2 m. Nutrient uptake by crops at harvest was determined in seeds and straw using the standard methods Jackson (1967), Black (1965). Nutrient uptake by seeds and linseed straw was calculated by multiplying the nutrient content by the corresponding dry matter. Ten days after the application of herbicides (DAH) and after crop harvest, soil samples 0–15 cm in depth were collected from each plot to determine dehydrogenase activity. Using the reduction of 2,3,5-triphenyl tetrazolium chloride to triphenylformazon (TPF), soil dehydrogenase activity was determined according to the methods of Tabatabai (1994). It was calculated in given units:

Dehydrogenase activity = C/3 × 24 = D µg TPF/g soil/hr

Using ether as a solvent, the method described in (AOAC 1970) was used to determine the oil content of the seeds. The oil content was expressed as a percentage on the basis of the oven-dried seed basis as follows:

$$\textbf{Oil (\%)} = \frac{\text{Weight of oil (g)}}{\text{Weight of sample (g)}} \quad X\ 100$$

The total oil yield per hectare was calculated by multiplying the seed yield (kg/ha) by the percentage of oil present in the seeds of each treatment. To evaluate the treatment differences, the data were statistically analyzed in accordance with Gomez and Gomez (1984) and assessed at a 5% level of significance. After square root transformation, $\sqrt{(x+1)}$), the weed count and weed dry weight data were examined, and the effects of the various treatments were evaluated using the transformed means.

Results and Discussion

Weed control

All weed management methods greatly improved the ability weedy checks to lower the overall weed count due to the decrease in species-wise weed count. The application of clodinafop propargyl (60 g/ha) + metsulfuron methyl (4 g/ha) in combination with isoproturon (1.25 kg/ha) resulted in a significantly lower total weed count than did the other treatments. Other weed control treatments, viz. hand weeding twice, and clodinafop propargyl (60 g/ha) + carfentrazone ethyl (10 g/ha), which are statistically similar to each other, were the other superior treatments in this regard (Table 1). A significant reduction in the number of different weed species caused by these treatments resulted in a lower total weed count because herbicide mixtures containing metsulfuron methyl and carfentrazone were effective at controlling grassy and broad-leaved weeds, respectively, while isoproturon had broad-spectrum control of weed species in different categories. Similarly, a lower weed count was recorded with the tank mix application of clodinafop + metsulfuron in wheat by Singh (2013). Among the nitrogen levels, the significantly lowest total weed count was recorded in the 100% RDN plots. Due to the better supply of nitrogen, the optimum plant stand for which the plants grow vigorously might have lowered the count of weeds. Moreover, 75% RDN was proven to be the next superior treatment. The maximum total weed count was found in the 5 t/ha FYM plots (Table 1). FYM, which was applied after one month of sowing, also served as an additional source of weed seeds and resulted in a greater total weed count. In general, dry matter accumulation was greatest at 150 DAS; thereafter, it decreased gradually. Weed withering was responsible for the decrease in dry weight of the weeds. A comparison of the weedy check and weed control treatments revealed that the total dry weight of the weeds was dramatically lower. The combination of clodinafop propargyl (60 g/ha) + metsulfuron methyl (4 g/ha) had the lowest dry matter accumulation of the total weeds. A lower dry weight of weeds with clodinafop and metsulfuron has also been reported by Singh *et al.* (2015) in wheat. Isoproturon (1.25 kg/ha) was the next best treatment for recording significantly lower dry matter accumulation in total weeds. The lower dry matter accumulation of total weeds was due to the presence of fewer weeds per unit area through effective control of weeds in these treatments. Among the nitrogen levels, the application of 100% RDN resulted in the lowest dry matter accumulation of the total weeds. The better growth/spread of plants due to better nutrition might have restricted the growth of weeds, as was the case for the other treatments. 75% RDN, which significantly decreased the dry matter buildup of total weeds over 5 t/ha, was the next superior treatment among the different nitrogen levels. As the crop was mainly infested with grassy weeds along with some proportion of broad-leaved weeds, clodinafop propargyl 60 g/ha + metsulfuron methyl 4 g/ha was found to be most effective for controlling weeds and achieved the highest weed control efficiency of approximately 78.8%. Isoproturon (1.25 kg/ha) closely followed this treatment, with a weed control efficiency of 77.2% due to improved weed control (Table 1). The higher weed control efficiency of clodinafop at 60 g/ha (Post.) in linseed was also reported by Thakur (2015). Siddesh *et al.* (2016) reported greater weed control efficiency with isoproturon in linseed. Two weed removal cycles in hand-weeded plots resulted in less dry matter accumulation of total weeds per unit area and achieved a better weed control efficiency of 75.5%. Among the different weed control treatments, a comparatively lower weed control efficiency (73.9%) was achieved with the application of clodinafop propargyl (60 g/ha) + carfentrazone ethyl (10 g/ha).

Yield

All the weed control treatments had significantly greater effects on increasing the yield of linseed than did the weedy check treatment (Table 1). The application of 1.25 kg/ha isoproturon resulted in a significantly greater seed yield (641.39 kg/ha), which was equivalent to two hand weedings (614.44 kg/ha). A reduced ability of crop-weed to compete for resources (sunlight, nutrients and space) resulted in significant improvements in growth and yield attributes, which ultimately contributed to increased seed yield in the linseed. Similar results were also reported by Siddesh *et al.* (2016) and Chopra and Paul (2015). These findings are in close conformity with those of Husain *et al.* (2003) and Angiras *et al.* (1991), who also reported a greater yield of linseed following isoproturon application. Clopidogrel (60 g/ha) + metsulfuron methyl (4 g/ha) was the other treatment that had the most significant effect on seed yield. Although clodinafop propargyl (60 g/ha) + carfentrazone ethyl (10 g/ha) was significantly superior to the weedy control, among the herbicides, it was least effective at recording higher seed yields. Among the nitrogen levels, the application of 100% RDN resulted in the significantly highest seed yield (557.12 kg/ha), followed by 75% RDN, with a seed yield of 516.80 kg/ha. The lowest seed yield of 462.22 kg/ha was recorded with the FYM treatment at 5 t/ha. The percent increase in seed yield through these superior treatments was 20.5 and 11.8% over the FYM 5 t/ha application. Similar results were reported by Berti *et al.* (2009) for flaxseed. All the weed control methods, excluding clodinafop propargyl (60 g/ha)

Table 1. Effects of weed control treatments and nitrogen levels on total weed count (No./m^2), total weed dry matter accumulation (g/m^2), weed control efficiency (%) at the maximum count stage, and seed and straw yield (kg/ha) of linseed

Treatment	Total weed Count (120 DAS)	Total weed dry weight (150 DAS)	Weed Control Efficiency (%)	Seed yield (kg/ha)	Straw yield (kg/ha)
Weed control					
Isoproturon 1.25 kg/ha	7.79 (60.33)	7.15 (50.44)	77.23	641.39	1373.21
Clodinafop propargyl 60 g/ha + metsulfuron methyl 4 g/ha	7.52 (56.56)	6.91 (47.07)	78.75	518.95	1159.73
Clodinafop propargyl 60 g/ha+ carfentrazone ethyl 10 g/ha	8.71 (75.56)	7.67 (57.97)	73.83	420.44	950.35
Hand weeding twice	8.46 (71.22)	7.42 (54.22)	75.53	614.44	1304.04
Weedy	16.37(269.00)	14.91 (221.54)	0.0	365.00	802.73
CD (P= 0.05)	0.57	0.20	-	27.30	149.76
Nitrogen Levels					
FYM 5 t/ha	10.83(129.20)	9.42(97.47)	-	462.22	1019.86
75% RDN	9.57 (102.67)	8.64 (82.81)	-	516.80	1115.02
100% RDN	8.92 (87.60)	8.38 (78.46)	-	557.12	1219.15
CD (P= 0.05)	0.44	0.15	-	21.14	116.00

The data were transformed to square root transformations ($\sqrt{x+1}$). The values given in parentheses are the means of the original values.

+ carfentrazone (10 g/ha), were found to be significantly better than the weedy check at increasing the straw yield of linseed (Table 1). The 1.25 kg/ha isoproturon treatment, which was comparable to two manual weeding treatment, produced considerably more straw than the other treatments. The increase in straw yield was 71.1, 62.5 and 44.5% with the application of isoproturon (1.25 kg/ha), hand weeding twice and clodinafop propargyl (60 g/ha) + metsulfuron methyl (4 g/ha), respectively, over the weedy. The application of 100% RDN resulted in a significantly greater straw yield of linseed. However, the application of 75% RDN also had a statistically similar effect. A lower straw yield was obtained with FYM 5 t/ha, but this yield was also comparable to that obtained with 75% RDN application. There was an increase of 19.5 and 9.3% in straw yield with the application of 100 and 75% RDN, respectively, compared with that with the application of FYM 5 t/ha. An increased supply of nitrogen through 100 and 75% RDN application helped the plants to grow vigorously with a higher dry matter content, which ultimately resulted in a greater straw yield than that resulting from the FYM 5 t/ha treatment.

Nutrient uptake by crops

The data given in Table 2 showed that all the weed control treatments were significantly superior to the weedy check treatment in terms of increasing the uptake of nitrogen, phosphorus and potassium by the seeds and straw of linseed. The greater uptake of nutrients in crops occurs because the effective control of weeds by these superior treatments created a competition-free environment, which lead to better establishment of plants with better root growth. This process help the plant to take up more nutrients and achieve higher yields (seed and straw) and thereby higher uptake, as the uptake is a multiple of yield (grain and straw) and respective nutrient content. In the seeds of the linseed crop, 1.25 kg/ha isoproturon was significantly superior for increasing uptake of nitrogen, which was followed by two rounds of hand-weeding. The opposite trend was found for a significantly greater uptake of phosphorus in the seeds of linseed. However, for a significantly greater uptake of potassium in comparison to the rest of the treatments, both of these treatments behaved similarly to each other. Clodinafop propargyl (60 g/ha) + metsulfuron methyl (4 g/ha) also resulted in significantly greater uptake of N, P and K in linseed seeds than did the other weed control methods. Among the weed control herbicides, the significantly lowest uptake of N, P and K by linseed seeds was found in the clodinafop propargyl 60 g/ha + carfentrazone ethyl 10 g/ha treatment. With respect to the uptake of nutrients in linseed straw, isoproturon (1.25 kg/ha), which is on par with hand weeding, had a significantly greater uptake of nitrogen, phosphorus and potassium than did the other weed control treatments. Clodinafop propargyl (60 g/ha) + metsulfuron methyl (4 g/ha) was the next superior treatment in this regard, followed by clodinafop propargyl (60 g/ha) + carfentrazone ethyl (10 g/ha).

Among the nitrogen levels, the significantly highest uptake of nitrogen, phosphorus and potassium in the seeds and straws of linseed was recorded with 100% RDN application. However, 75% RDN was also at par with the other treatments for recording considerably greater uptake of phosphorus and, subsequently, for nitrogen and potassium uptake in linseed seeds. Likewise, the application of 75% RDN was proven to be the next best treatment for recording greater uptake of nitrogen, phosphorus and potassium in linseed straw. A higher yield (seed and straw) and nutrient content in the seeds and straw due to better nutrient delivery from these treatments resulted in greater uptake of important nutrients since uptake is a function of production and nutrient content.

Table: 3. Effects of weed control treatments and nitrogen levels on nutrient uptake (kg/ha) and dehydrogenase activity in soil (µg TPF/g soil/hr)

Treatment	Nutrient uptake						Dehydrogenase activity	
	Nitrogen		Phosphorus		Potassium			
	Seed	Straw	Seed	Straw	Seed	Straw	10 DAH	At harvest
Weed Control								
Isoproturon 1.25 kg/ha	46.21	65.12	3.97	11.19	14.48	47.05	2.13	3.18
Clodinafop propargyl 60 g/ha + metsulfuron methyl 4 g/ha	35.82	47.54	3.58	9.13	13.68	37.18	1.80	2.60
Clodinafop propargyl 60 g/ha + carfentrazone ethyl 10 g/ha	28.69	36.04	3.03	6.86	12.14	30.28	1.71	2.36
Hand weeding twice	39.64	58.76	4.36	10.35	14.88	44.08	2.63	3.56
Weedy	18.99	29.74	1.33	5.58	6.77	23.53	2.31	3.28
CD (P=0.05)	2.08	6.80	0.34	1.15	0.63	4.91	0.37	0.43
Nitrogen Levels								
FYM 5 t/ha	30.59	41.07	2.96	7.55	11.20	31.92	2.22	3.07
75% RDN	34.18	47.00	3.29	8.63	12.53	36.30	1.97	2.97
100% RDN	36.74	54.26	3.51	9.68	13.45	41.05	2.16	2.95
CD (P=0.05)	1.61	5.27	0.27	0.89	0.49	3.80	NS	NS

These results were in close proximity with those of Upadhyay *et al*. (2012), in which N uptake increased with increasing nitrogen application in linseed due to increased N availability. Considerably lower uptake of N, P and K from both the seeds and straw was recorded in the 5 t/ha FYM-treated plots.

Dehydrogenase activity

The dehydrogenase activity in the hand-weeded plots was significantly greater than that in the other weed control herbicide treatments (Table 2). The enzymatic activity observed in the weedy check was also significantly similar to that observed after two manual weedings at both observation stages. The application of herbicides resulted in reduced enzymatic activity compared to that in untreated plots (i.e., after two rounds of hand weeding and weedy check) after 10 days of herbicide application and at harvest. Among the herbicides tested in this study, 1.25 kg/ha isoproturon was shown to have least detrimental effect on microbes, as indicated by the small effect on dehydrogenase activity compared to that of the other herbicides (clodinafop propargyl 60 g/ha + metsulfuron methyl 4 g/ha and clodinafop propargyl 60 g/ha + carfentrazone ethyl 10 g/ha). The dehydrogenase activity in the 1.25 kg/ha isoproturon-treated plots was statistically similar to the enzymatic activity in the weedy check at both stages of observation. Additionally, the recovery of dehydrogenase activity was greater for 1.25 kg/ha isoproturon than for the other herbicides at the harvest stage of the crop. These findings are consistent with those of Jha *et al*. (2014), who reported higher dehydrogenase activity in hand-weeded plots and reduced activity with the application of clodinafop alone or in combination with other herbicides in soybean crop. Although the effects were non-significant at different nitrogen levels, numerically, the maximum dehydrogenase activity was reported in the FYM 5 t/ha treatment at both observation stages (i.e., 10 days after herbicide use and at harvest). There was a decrease in dehydrogenase activity with a higher dose of nitrogen at both observation stages. These results are in close conformity with the findings of Macci *et al*. (2012), who noted that dehydrogenase activity increased in organic treatment. With inorganic fertilizer, less influence on dehydrogenase activity was found in the studies carried out by Xie *et al*. (2009) and Romero *et al*. (2010).

Seed quality

Among the weed control treatments, all the treatments except for clodinafop propargyl (60 g/ha) + carfentrazone ethyl (10 g/ha) were considerably superior to the weedy check in terms of increasing the oil content of the linseed (Table 3). Isoproturon (1.25 kg/ha) was at par with hand-weeding twice,

Table 4. Effects of weed control treatments and nitrogen levels on the oil content (%) and oil yield (kg/ha) of linseed

Treatment	Oil content (%)	Oil yield (kg/ha)
Weed Control		
Isoproturon 1.25 kg/ha	35.04	224.67
Clodinafop propargyl 60 g/ha + metsulfuron methyl 4 g/ha	34.19	178.00
Clodinafop propargyl 60 g/ha +carfentrazone ethyl 10 g/ha	32.66	137.65
Hand weeding twice	34.82	214.16
Weedy	31.90	116.48
CD (P=0.05)	1.46	10.95
Nitrogen Levels		
FYM 5 t/ha	33.18	154.83
75% RDN	33.52	174.84
100% RDN	34.47	192.91
CD (P=0.05)	NS	8.48

and clodinafop (60 g/ha) and metsulfuron methyl (4 g/ha) were considerably superior to the other treatments for increasing the oil content of linseed. Although nitrogen levels did not significantly influence the oil content of the linseed, numerically, there was an increase in the oil content with successive increases in nitrogen dose, and the highest content was found with 100% RDN application over FYM 5 t/ha application. This was probably due to the presence of healthier seeds with higher seed weights in the treatment fertilized with a higher dose of nitrogen. All of the weed management methods considerably increased the amount of linseed oil produced compared to that produced by the weedy check (Table 3). Like hand-weeding, 1.25 kg/ha isoproturon had a significantly greater oil yield than the other treatments. Clodinafop propargyl (60 g/ha) + metsulfuron methyl (4 g/ha) was the other finest treatment in this regard. There was an increase of 9.29 and 8.39% in oil yield with the application of isoproturon (1.25 kg/ha) and after two rounds of hand-weeding, respectively, compared with the weedy check. The increase in oil yield was due to the high oil content and seed yield in these treatments. A significantly lower oil yield was obtained in the weedy check. Hussein *et al*. (2000) also reported considerable losses in the oil yield of linseed due to the presence of weeds. The application of 100% RDN resulted in the significantly highest oil yield (192.9 kg/ha), followed by 75% RDN (174.8 kg/ha). The increase in these two treatments were 19.7 and 12.9%, respectively, than that in the FYM 5 t/ha treatment. Because the oil yield is a multiple of seed yield and oil content, the higher seed yield obtained in these superior treatments resulted in a greater oil yield, as the oil content was not significantly influenced by nitrogen levels.

Conclusion

Hence, the results of the present study showed that effective weed control, increased nutrient uptake and increased yield of linseed can be achieved through the application of 1.25 kg/ha (Post.) with a 100% recommended dose of nitrogen without having a phytotoxic effect on the crop.

Conflict of interest

The authors declare that they have no conflicts of interest.

References

Anonymous. (2019). Project Coordinators Report, All India Coordinated Research Project on Linseed. Annual Group Meeting Report Unpub.: 15.

Angiras, N. N., Badiyala, D. & Singh, C. M. (1991). Comparative efficacy of herbicides for weed control in Flax (*Linum usitatissimum*L.). *Indian Journal of Weed Science,* 33, 19-23.

AOAC. (1970). Methods of analysis. Association of Official Agricultural Chemists, Washington, D.C. Edn.3: 185.

Berti, M., Fischer, S., Wilckens, R. & Hevia, F. (2009). Flaxseed response to N, P and K fertilization in south central chile. *Chilean Journal of Agricultural Research,* 69, 145-153.

Black, C. A. (1965). Method of soil analysis. *Current Science,* 25, 259-260.

Chopra, P. & Paul, S. (2015). Evaluation of pre- and postemergence herbicides in linseed under submountain Himalayan region. In *25th Asian-Pacific Weed Science Society Conference on "Weed Science for Sustainable Agriculture, Environment and Biodiversity"*, Hyderabad, India during 13-16 October, 2015.

Dordas, E. (2010). Variation of physiological determinants of yield in linseed in response to nitrogen fertilization. *Industrial Crops and Products,* 31, 455-465.

Genser, A. D. & Morris, N. D. (2003). History of cultivation and uses of flaxseed. In: *Flax -The genus Linum*. (Muir AD and Westcott ND, eds.). Taylor and Francis, London.

Gomez, K. A. & Gomez, A. A. (1984). Statistical procedure for agricultural research.2nd edition. Wiley Inter Science, New York, USA p 680.

Husain, K., Tewari, A. N. & Singh, K. (2003). Bioefficacy of isoproturon and 2,4-D in linseed grown under irrigated conditions of Uttar Pradesh. *Indian Journal of Weed Science,* 35, 153.

Hussein, H. F., El-Hariri, D. M. & Hassain, M. S. (2000). Response of some flax (*Linum usitatissimum* L.) cultivars and associated weeds to weed control treatments. *Egyptian Journal of Agronomy,* 24, 23-42.

Jackson, M. L. (1967). Soil chemical analysis. Prentice Hall of India Limited, New Delhi.

Jha, B. K., Chandra, R. & Singh, R. (2014). Influence of post emergence herbicides on weeds nodulation and yields of soybean and soil properties. *Legume Research,*37, 47-54.

Kumar, M., Tirth, R., Uttam, S. K., Kumar, K. & Parihar, G. S. (2015). Production potential of Linseed (*Linum usitatissimum* L.) under different crop sequences and nitrogen application in rainfed conditions. *International Journal of Agriculture Innovations and Research,* 3, 1018-1022.

Meena, R. L, Singh, T. K., Kumar, R., Aniruddha, R. & Om, H. (2011). Production potential and economics of linseed (*Linum usitatissimum*L.) as influenced by fertility levels and seed rates in dryland conditions. *Environment and Ecology,*29, 456-458.

Macci, C., Doni, S., Peruzzi, E., Masciandro, G., Mennone, C. & Ceccanti, B. (2012). Almond tree and organic fertilization for soil quality improvement in Southern Italy.*Journal of Environmental Management,* 95, 215-222.

Mishra, A. & Tosh, G. C. (1979). Chemical weed control studies on dwarf wheat. *Journal of Research Orissa University of Agricultural Science and Technology,* 10, 1-6.

Romero, E., Fernandez, B. J., Diaz, J. & Nogales, R. (2010). Enzyme activities and diuron persistence in soil amended with vermicompost derived from spent grave marc and treated with urea. *Applied Soil Ecology,* 44, 198-204.

Siddesh, G., Chittapur, B. M., Biradar, S. A., Koppalkar, B. G. &Swamy, M. (2016). Bioefficacy of herbicides for weed management in linseed (*Linum usitatissimum*L.). *Journal of Farm Sciences,* 29, 19-22.

Singh, S., Dhaka, A. K. & Hooda, V. S. (2015). Evaluation of Traxos 5% EC (Pinoxaden + Clodinofoppropargyl) against *Phalaris minor* and other grassy weeds in wheat. *Haryana Journal of Agronomy,*31, 1-8.

Singh, T. (2013). Weed management in irrigated wheat (*Triticum aestivum*) through tank mix herbicides in Malwa Plateau of Central India. *Indian Journal of Agronomy,*58, 525-528.

Tabatabai, M. A. (1994). Soil enzymes. *In: methods of Soil Analysis. Part 2. Microbiological and biochemical properties.* (Weaver RW, Angeley S, Bottomley P, Bezdick D, Smith S, Tabatabai A, Wollum A, Eds). SSSA Book Series No., Madison(WI): SSSA. pp 775-833.

Thakur, M. (2015). Chemical weed control in dual purpose linseed (*Linum usitatissimum*L.) under mid hill conditions. M. Sc. Thesis, Department of Agronomy, CSKHPKV Palampur, India.

Toure, A. & Xueming, Xu. (2010). Flaxseed Lignans: Source, biosynthesis, metabolism, antioxidant activity, bioactive components and health benefits. *Comprehensive Reviews in Food Science and Food Safety,* 9, 261-269.

Upadhyay, S., Tiwari, D. N.& Kumar S. (2012). Effect of nitrogen and sulphur on dry matter accumulation, nitrogen and sulphur uptake and chlorophyll content in linseed (*Linum usitatissimum*L.) cv. Neelam. *Indian journal of Life Sciences,*2, 105-107.

Xie, W., Zhou, J., Wang, H., Chen, X., Lu, Z., Yu, J. & Chen X. (2009). Short term effects of copper, calcium and cypermethrin on dehydrogenase activity and microbial functional diversity in soils after long term mineral or organic fertilization. *Agriculture Ecosystems and Environment,* 129, 450-456