Scientific Papers. Series A. Agronomy, Vol. LXVI, No. 2, 2023
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

WEEDS CONTROL IN INDUSTRIAL HEMP (*Cannabis sativa* L.) BY USING HERBICIDES IN PRE-EMERGENCY AND POST-EMERGENCY

Ioan PUIU[1], Lorena-Diana POPA[2], Carmen Simona GHIȚĂU[1], Costel SAMUIL[1], Constantin LUNGOCI[1], Laurențiu PINTRIJEL[3]

[1]Iasi University of Life Sciences "Ion Ionescu de la Brad" (IULS), M. Sadoveanu Alley 3, Iasi, 700490, Romania
[2]Agricultural Research and Development Station, 377 Principala Street, Secuieni, 617415, Neamt, Romania
[3]Brado Agri S.R.L., Vascauti, 727394, Suceava, Romania

Corresponding author email: constantinlungoci@uaiasi.ro

Abstract

The impressive production potential of industrial hemp (Cannabis sativa L.) is limited by the lack of herbicides authorized for use in this crop in Romania. The aim of this research was to establish the tolerance of industrial hemp to herbicides applied in preemergence and postemergence to control dicotyledonous weeds: Amaranthus retroflexus L., Atriplex patula L., Chenopodium album L., Polygonum convolvulus L., Sinapis arvensis L., Xanthium strumarium L., respectively monocotyledonous: Echinochloa crus-galli L., Setaria spp., Sorghum halepense (L.) Pers. and Poa annua L. A number of 13 herbicides were tested, and the results demonstrate that monocotyledonous weeds can be controlled very well by the active substances cletodim (89.67%) and fluazifop-P-butyl (91.33%), and dicotyledonous weeds are effectively combated by aclonifen (80.0%) applied in pre-emergence and oxyfluorfen (84.0%) applied pre-emergence, but oxyfluorfen causes phytotoxicity (9.0%) of the treated hemp plants. Also, the good effect of clopiralid on Xanthium strumarium and other weeds from the Asteraceae family should be mentioned.

Key words: *herbicides, industrial hemp, phytotoxicity, weed control.*

INTRODUCTION

Cannabis sativa L., known as industrial hemp, is an herbaceous, annual plant belonging to the Cannabaceae family. Traditionally, hemp plants were primarily cultivated as a fibre crop for the production of textiles and ropes, especially in Eastern Europe and the Western world. Romania was the largest exporter of hemp fibre in Europe before 1989, ranking third globally, and possessed advanced spinning and weaving technology. The cultivated area for industrial hemp in Romania was 49.000 ha before 1990 (Roman et al., 2012). However, in recent years, the actual cultivated hemp acreage has been between 1.000-3.000 ha due to the lack of processing facilities.

Industrial hemp is cultivated for seeds and fibres and has numerous application fields, including food (oil, flour, and de-hulled seed), animal protein feed, animal bedding, cosmetics, industry (textiles, building materials, paper, composites, automotive, pharmacology, etc.) (Farinon et al., 2020). Thanks to its highly developed root system, which surpasses that of other herbaceous plants, hemp is well-suited for phytoremediation of soil contaminated with heavy metals and pesticides (Mihoc et al., 2012). Industrial hemp experts consider it a low-input crop, requiring minimal use of chemicals, fertilizers, water, and pesticides, and it has a positive impact on the environment, contributing to carbon sequestration (Hayo, 2004).

In other crops, cultural practices for weed control, including the use of herbicides, are well-established (Trotus et al., 2020). However, only a limited number of studies have concentrated on weed management strategies with herbicides in hemp production (Flessner et al., 2020). The aim of this research was to identify technological solutions for effectively combating weeds in industrial hemp cultivation using herbicides while minimizing adverse impacts on the environment.

Hemp plants cultivated for seeds are highly susceptible to weed infestation during the initial 30 days of growth, primarily because of the low plant density, which typically ranges from 30 to 40 plants per square meter (Gauca, 2012). There exists a direct correlation between plant density and the effectiveness of weed control (Vera et al., 2002).

The primary goal of this paper is to investigate the degree of herbicide selectivity in hemp fields and the effectiveness of herbicide applications in the control of weed species within hemp cultivation.

Areas under hemp cultivation often exhibit a high degree of weed infestation during the initial growth stages, encompassing both dicotyledonous and monocotyledonous weeds, whether annual or perennial. The prevalence of these weeds varies according to the pedo-climatic conditions in the northeastern region of Romania (Puiu et al., 2022).

In the course of this research, 13 herbicides commonly used in the cultivation of other field crops were tested. These herbicides were applied in accordance with the plant cultivation procedures, both in the pre-emergence and post-emergence stages.

The selection of herbicides was based on a comprehensive review of previous worldwide research pertaining to hemp cultivation and the specific modes of action associated with these herbicides (Laate, 2012; Trotus et al., 2020).

MATERIALS AND METHODS

The experiments were carried out on the non-irrigated fields at the Milen Tech SRL farm, located in Ripiceni village, Botosani county, in order to test a range of 13 herbicides in hemp production (8 pre-emergent herbicides and 5 post-emergent herbicides).

The experimental model: a randomized complete block design with 8 variants and 4 replications for 8 herbicides applied in pre-emergence and a block of 5 variants and 4 replications for 5 herbicides applied in post-emergence (Jitareanu, 1999) (Table 1).

Each experimental plot covered an area of 21 square meters (3.00 x 7.00 meters). Additionally, an untreated check plot was included for comparison.

Table 1. Pre and post-emergent herbicides tested for weed control in hemp production

No	Product	Active ingredient	Product rate, kg, l/ha	Source
Preemergent herbicides				
1	As Super	Metribuzin 700 g/l	1.2	Sharda
2	Challenge 600	Aclonifen 600 g/l	4.0	Bayer
3	Clomate	Clomazone 360 g/l	0.3	Albaugh
4	Dual Gold 960	S-metolachlor 960 g/l	1.5	Syngenta
5	Goal 4 F	Oxifluorfen 480 g/l	0.5	Dow Agro
6	Modown 4 F	Bifenox 480 g/l	1.5	ADAMA
7	Stomp Aqua	Pendimetalin 455 g/l	3.0	BASF
8	Venzar 500	Lenacil 500 g/l	0.8	FMC Agro
Postemergent herbicides				
1	Basagran	Bentazon 480 g/l	2.5	BASF
2	Buctril Universal	Bromoxinil 280 g/l +acid 2,4-D 280 g/l	0.8	Bayer
3	Fusilade Forte	Fluazifop-P-butil 150 g/l	1.2	Syngenta
4	Lontrel 300	Clopyralid 300 g/l	0.5	Dow Agro
5	Select Super	Cletodim 120 g/l	1.5	UPL

The biological material used in the experiment was a monoecious hemp variety with a specific focus on seed production: Secuieni - Jubileu (sourced from the Agricultural and Development Research Station Secuieni in Neamt County, Romania).

The experiment was conducted on cambic chernozem soil with the following characteristics: a pH level of 6.5, a humus content of 2.8%, a nitrogen concentration of 0.22%, a P_2O_5 content of 27 ppm, and K_2O content of 191 ppm.

In the autumn of the year preceding the research, following the harvest of the previous crop (winter wheat), plowing was conducted to a depth of 30 cm, followed by leveling using a disk harrow.

From a climatic perspective, the temperature was in close alignment with the 60-year average for the region. However, notable deviations from the multi-year average were observed in terms of rainfall.

For instance, the month of May experienced abundant rainfall (122.7 mm, compared to the monthly average of 76.9 mm), while the month of August was exceptionally dry (5.8 mm, contrasting with the usual 59.8 mm) (Figure 1).

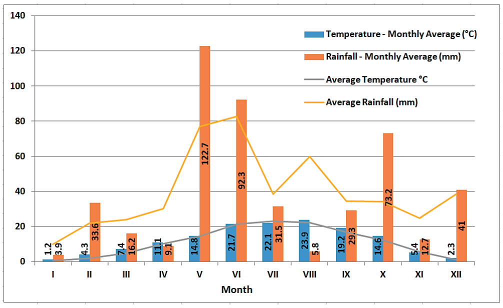

Figure 1. The climatic conditions in Ripiceni in 2020

In the spring, soil preparation for seed germination took place one day before sowing using a harrow. Fertilization was conducted using a complex fertilizer of N:P:K type 15:15:15, with an application rate of 400 kg per hectare, applied during the soil preparation. Additionally, 100 kg per hectare of ammonium nitrate (33.5% nitrogen) was applied during the vegetation phase when the plants had 6 to 8 leaf pairs (BBCH 16-18).

Hemp seeds were sown on April 27, 2020, using a Monosem precision seeder. The planting rate was set at 6 kg per hectare, and the seeds were sown at a depth of 4.0 cm with row spacing of 45.0 cm. The density was 32 plants/square meter.

The pre-emergence herbicides were applied on May 1st, while the post-emergence herbicides were applied 30 days after sowing, when the hemp plants had reached a height of approximately 25-30 cm and they were at the 8-10 leaf pairs stage. The application was carried out using a volume of 250 l/ha.

The evaluation of herbicides' impact on hemp plants included assessments of phytotoxicity and plant vigor. Additionally, the effectiveness of the treatments in controlling the target weeds varied depending on the specific herbicide used.

To assess phytotoxicity, hemp plants were rated for visible injury, including chlorosis and necrosis. The ratings were done on a scale ranging from 0 (no visible injury) to 100% (complete leaves/plants necrosis), following the method described by Fehr et al. (1971).

To evaluate the vigor of the plants, measurements were taken for plant height and leaf mass, with 100% representing values equal to those of the non-treated control.

To determine the effectiveness of herbicides against weeds, a rating system was employed, where grade 0 indicated unaffected weeds and 100% denoted necrotic or dry weeds.

For the herbicides applied pre-emergence and post-emergence, the evaluation was carried out after 2, 4, 6 and 8 weeks after the treatment.

The evaluated effect of herbicides was done for the follow weed species:

- dicotyledonous: *Amaranthus retroflexus* L., *Atriplex patula* L., *Chenopodium album* L., *Polygonum convolvulus* L., *Sinapis arvensis* L. *and Xanthium strumarium* L.;
- monocotyledonous: *Echinochloa crus-galli* L., *Setaria* spp., *Sorghum halepense* (L.) Pers. and *Poa annua* L.

The hemp harvest took place on September 5, 2020. To determine hemp seed yields, samples were collected from a 5.0 square meter area located at the centre of each plot. The seed yield was assessed by manually harvesting. Subsequently, the harvested material was dried at 35°C.

Data were analysed by ANOVA followed by a post hoc Tukey test ($p < 0.05$). Normality and homogeneity of variances were tested before the Tukey test. The program used was IBM SPSS v14.0 (Armonk, NY: IBM Corp.), results were expressed as means.

RESULTS AND DISCUSSIONS

The testing of hemp herbicides in both pre- and post-emergence has revealed significant differences among the herbicides, concerning the tolerance of hemp plants to herbicides, as well as the herbicides efficiency of fighting dicotyledonous and monocotyledonous weeds.

All the herbicides used in pre-emergence show phytotoxicity in hemp, at the first evaluation, (4.67-43.00%), with one exception: Challenge 600 (aclonifen) wich did not cause any visible symptoms in hemp (1.67%).

The highest level of phytotoxicity in hemp, observed 8 weeks after treatment, was associated with As Super (metribuzin) (35.00%) and Clomate (clomazone) (80.67%).

The phytotoxicity of Dual Gold 960 (S-metolachlor) was 25.33% and by Goal 4 F (oxyfluorfen), Modown 4 f (bifenox) and Stomp Aqua (pendimethalin) between 9.00 and 11.00%. In the case of Venzar (lenacil), at the first evaluation the injury level was 14.33%, and after 8 weeks only 6.0% (Figure 2).

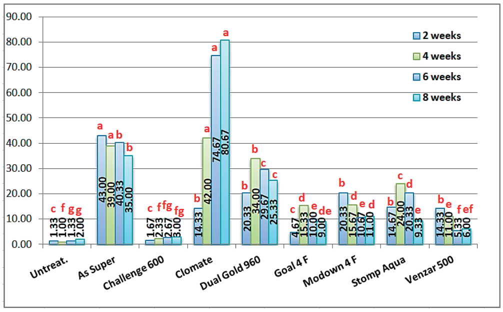

Figure 2. Evaluation of phytotoxicity of hemp treated with pre-emergent herbicides (%)

The height of hemp plants was negatively affected by the majority of the active ingredients used in pre-emergence, especially four weeks after herbicide application. Metribuzin, clomazone, S-metolachlor, oxyfluorfen, bifenox and pendimethalin all led to reductions in plant height. As Super (63.33%) and Clomate (75.33%) were the most harmful (Figure 3).

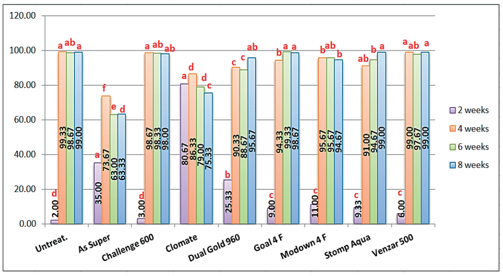

Figure 3. Evaluation of vigour of hemp treated with pre-emergent herbicides (%)

Out of the 8 active ingredients tested pre-emergence, it is notable that aclonifen (80.0%) and oxyfluorfen (84.0%) exhibited effective control over the studied dicotyledonous weeds. Oxyfluorfen, despite its efficacy, had a phytotoxic effect on hemp plants.

In the case of metribuzin, it effectively controlled dicotyledonous weeds. However, it is crucial to note that metribuzin cannot be used for hemp cultivation because it has a severe adverse impact on hemp plants. On the other hand, the active substances clomazone, s-metolachlor, bifenox, pendimethalin and lenacil did not offer sufficient protection for hemp.

The herbicide s-metolachlor effectively controls monocotyledonous weeds in the early stages of hemp growth and is relatively well tolerated by hemp plants, with plant vigor ranging between 88.67% and 95.67% (Figure 4).

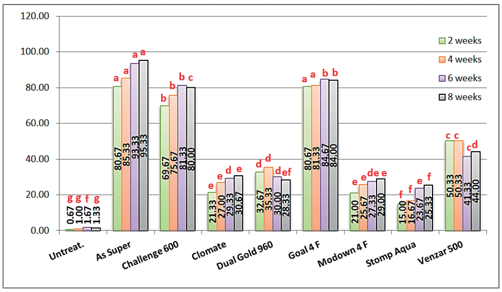

Figure 4. Evaluation of efficiency of pre-emergent herbicides against weeds (%)

Among the post-emergence herbicides used in hemp, including Basagran, Buctril Universal, Fusilade Forte, Lontrel 300 and Select Super, they initially exhibited phytotoxic effects on hemp during the first 2 weeks after treatment, with phytotoxicity ranging from 1.0% to 34.0%. However, after 8 weeks of treatment, bentazon caused severe damage to hemp plants (65.0%), while bromoxynil had a lesser impact (14.67%). Fluazifop-p-butyl, clopyralid, and clethodim no longer affected hemp plants (Figure 5).

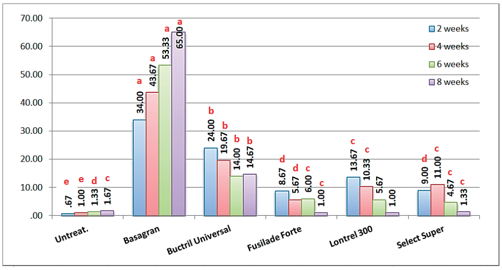

Figure 5. Evaluation of phytotoxicity of hemp treated with post-emergent herbicides (%)

Regarding the hemp vigour, at the first evaluation, the plants are affected in all variants (75.33-95.67%) (Figure 6).

After 8 weeks from herbicides application, only the hemp treated with the active ingredients bentazon (69.00%) and bromoxynil (90.33%) exhibites reductions in height.

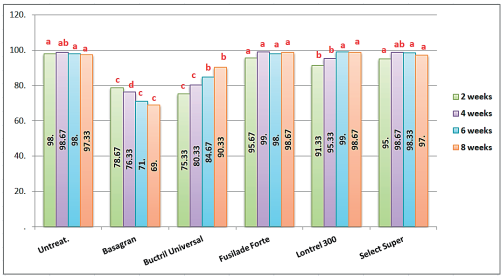

Figure 6. Evaluation of vigour of hemp treated with post-emergent herbicides (%)

This sugests that the hemp plants can recover from the impact of some harmful herbicides during the phases following application.

For the control of monocotyledonous weeds, the ingredients fluazifop-p-butyl (91.33%) and clethodim (89.67%) recorded a high efficiency and clopyralid controlled 61.0% of dicotyledonous weeds (especially weeds from the *Asteraceae* family, eg *Xantium strumarium* L., the most spread and harmful weed in hemp fields).

Bentazon and bromoxynil effectively combated dicotyledonous weeds. However, it's important to note that these herbicides are phytotoxic to hemp and are not suitable for use in hemp cultivation (Figure 7).

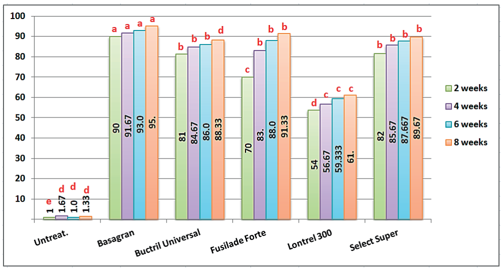

Figure 7. Evaluation of efficiency of post-emergent herbicides against weeds (%)

The control of dicotyledonous weeds in post-emergence is very difficult in hemp, because the plants are very sensitive to the application of specific herbicides.

The monocotyledonous weeds can be effectively combated by specific herbicides, because these are selectiv for hemp and have low phytotoxicity.

The production of hemp seeds varied depending on the effectiveness of the herbicide in controlling weeds and the selectivity of the products against hemp plants.

In the case of pre-emergence herbicides, the highest seed production was observed in the variant treated with Challenge (989.0 kg/ha), followed by Goal 4 F (949.7 kg/ha) and Dual Gold 960 (882.7 kg/ha). The untreated check yielded 766.3 kg/ha (Table 2).

Table 2. The influence of pre-emergent herbicides on hemp grain yield

Plots	Yield (kg/ha)	Difference (%)	Difference (kg)	Meaning
Challenge 600	989.0	129.06	222.7	***
Goal 4 F	949.7	949.7	183.4	***
Dual Gold 960	882.7	882.7	116.4	***
Untreat.	766.3	766.3	0.0	unt.
Stomp Aqua	650.7	650.7	- 115.6	000
Modown 4 F	630.7	630.7	- 135.6	000
As Super	570.3	570.3	- 196.0	000
Venzar 500	542.0	542.0	- 224.3	000
Clomate	443.3	443.3	- 323.0	000
LSD 5%	14.2	kg/ha		
LSD 1%	19.6			
LSD 0.1%	27.0			

Among the post-emergence herbicides, Lontrel 300 resulted in the highest seed production (936.7 kg/ha), followed by Select Super (911.7 kg/ha) and Fusilade Forte (893.0 kg/ha). The untreated check yielded 741.7 kg/ha (Table 3).

Table 3. The influence of post-emergent herbicides on hemp grain yield

Plots	Yield (kg/ha)	Difference (%)	Difference (kg)	Meaning
Lontrel 300	936.7	126.29	195.0	***
Select Super	911.7	122.92	170.0	***
Fusilade Forte	893.0	120.40	151.3	***
Untreat.	741.7	100.0	0.0	unt.
Buctril Universal	682.0	91.35	-59.7	000
Basagran	521.7	70.34	-220.0	000
LSD 5%	13.8	kg/ha		
LSD 1%	19.6			
LSD 0.1%	28.3			

In both application variants of the mentioned herbicides, seed productions are notably higher compared to the untreated control.

CONCLUSIONS

The herbicides tested on hemp, applied pre- and post-emergence in the field, exhibited varying levels of selectivity towards hemp and efficiency in controlling mono- and dicotyledonous weeds.

Throughout the research, selective herbicides were identified that provide effective weed control, while protecting hemp in the field.

Among the herbicides applied in pre-emergence, Challenge 600 herbicide was well-tolerated by hemp and proved to be highly effective. Goal 4 F also effectively controlled dicotyledonous weeds and was selective enough to allow for robust hemp production. Dual Gold 960 can be considered for protecting hemp crops as well.

On the other hand, As Super and Clomate herbicides exhibited significant phytotoxicity towards hemp. Additionally, Modown 4 F, Stomp Aqua, and Venzar 500 were not very efficient in weed control, and it is advisable to avoid their use in hemp cultivation.

In post-emergence applications, Lontrel 300 effectively controlled dicotyledonous weeds, while Select Super and Fusilade Forte were successful in combating monocotyledonous weeds. However, herbicides such as Buctril Universal and Basagran were phytotoxic to hemp and should not be used in hemp production.

The highest grain production was achieved in tests with pre-emergence herbicides, particularly Challenge 600 (989.0 kg/ha) and Goal 4 F (949.7 kg/ha), surpassing the yield of the untreated check, which was 766.3 kg/ha.

In the case of post-emergence herbicide applications, the best production results were seen in the variant with Lontrel 300 (936.7 kg/ha), followed by Select Super (911.7 kg/ha). Again, the untreated check yielded 741.7 kg/ha.

Based on the findings, a strategy for protecting hemp crops against weeds can be developed. This strategy includes the use of a pre-emergence herbicide like Challenge 600 or Goal 4 F, in addition to two post-emergence herbicides applied separately. These post-emergence herbicides can be Select Super or Fusilade Forte to combat monocotyledonous weeds and Lontrel 300 to control dicotyledonous weeds.

Furthermore, it's essential to implement all the necessary technological steps to protect the hemp crop during the initial phases of growth. This may involve crop rotation, mulching, selecting the right sowing date, adjusting the seed rate per hectare, and employing mechanical weeding as needed.

REFERENCES

Farinon, B., Molinari, R., Costantini, L., Merendino, N. (2020). The seed of industrial hemp (*Cannabis sativa* L.): Nutritional Quality and Potential Functionality for Human Health and Nutrition. *Nutrients*, *12*(7): 1935. doi:10.3390/nu12071935.

Fehr, W.R., Caviness, C.E., Burmood, D.T., Penningt, J.S. (1971). Stage of development descriptions for soybeans, *Glycine max* (L) Merrill. *Crop Science, 11.* 929–931.

Flessner, M.L., Bryd, J., Bamber, K.W., Fike J.H. (2020). Evaluating herbicide tolerance of industrial hemp (*Cannabis sativa* L.). *Crop Science*, *60*(1), 419–427. doi:10.1002/csc2.20055.

Gauca, C. (2012). *The technology of growing hemp for seed*. Secuieni, RO: SCDA Secuieni.

Hayo, M. G. van der Werf. (2004). Life Cycle Analysis of field production of fibre hemp, the effect of production practices on environmental impacts, *Euphytica*, 13-23.

Jitareanu, G. (1999). *Agricultural experimental technique*. Iasi, RO: "Ion Ionescu de la Brad" Publishig House.

Laate, E. (2012). *Industrial Hemp Production in Canada Alberta Agriculture and Rural Development*. Government of Alberta.

Lungoci, C., Motrescu, I., Filipov, F., Jitareanu, C., Teliban, G.C., Ghitau, C.S., Puiu, I., Robu T. (2022). The Impact of Salinity Stress on Antioxidant Response and Bioactive Compounds of *Nepeta cataria* L. *Agronomy, 12.* 562. doi:10.3390/agronomy12030562.

Mihoc, M., Pop, G., Alexa, E. & Radulov, I. (2012). Nutritive quality of Romanian hemp varieties (*Cannabis sativa* L.) with special focus on oil and metal contents of seeds. *Chem. Cent. J., 6*, 122. doi:10.1186/1752-153X-6-122.

Puiu, I., Popa, L.D., Robu, T., Ghitau, C.S., Topa, D., Lipsa, F., Teliban, G.C. (2022). Research on the optimization of the industrial hemp cultivation technology for the full use of biomass. *Lucrări Ştiinţifice, Seria Agronomie, Vol. 65*(2), 85–88.

Roman, G. V., Morar, G., Robu, T., Stefan, M., Tabara, V., Axinte, M., Borcean, I., Cernea, S. (2012). *Fitotehnie. Vol. II. Plante tehnice, medicinale si aromatice*. Bucharest, RO: Editura Universitara.

Trotuș, E., Isticioaia, S.F., Mîrzan, O., Popa, L.D., Naie, M., Lupu, C., Leonte, A., Pintilie, P.L., Buburuz, A.A., Pleșcan, I.D. (2020) - *Tehnologii de cultivare a unor plante de câmp pentru Zona Centrală a Moldovei.* Iasi, RO: Editura “Ion Ionescu de la Brad”.

Vera, C.L., Moskal, G.J., Malhi, S.S., Leach, D.W. (2002). *Plant Population and Weed Control in Hemp Production*. Agriculture and Agri-Food Canada.