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Sugar Beet Weeds in Tadla Region (Morocco): Species Encountered, Interference and Chemical Control

Y. Baye[1], A. Taleb[2] and M. Bouhache[3]
[1]Centre Régional de la Recherche Agronomique de Tadla, Beni Mellal,
[2,3]Institut Agronomique et Vétérinaire Hassan ll, Rabat,
Morocco

1. Introduction

Sugar beet occupies each year about 65.000 hectares in Morocco which allows a production that approaches or exceeds three million tons of roots, with an average yield of 46 tonnes per ha (54% of national needs sugar consumption). Since its introduction in Morocco in 1962-1963, sugar beet yield increased significantly in quantity and quality. In Morocco, the sugar beet is a very important crop because of its products and by-products, mainly:

- Production of sugar for sugar consuming population.
- Producing leaves, beet tops and pulp wet and dry food that are essential for cattle sheep that is either intended for milk production or to that of meat. It is important to note that major investments such as installation of various agro-industrial units were made.

In Morocco, sugar beet is planted from September through June - July. Yield obtained by farmers, averaging 46T/ha, is significantly below the request potential that would be 90 to 100 T/ha. Many factors contribute to low sugar beet production. Poor stand establishment, inadequate weed control, inadequate insect control and inadequate nitrogen fertilization are the main causes of low tonnage and poor quality sugar beet in Morocco.

The sugar beet is an important strategic crop in the irrigated perimeter of Tadla. During these 5 last years, an annual surface of 12000 ha is emblaved by this crop representing 23% / of the national area. The average yield obtained in the region is approximately 45 to 50 T/ha, which is very low compared to the potential yield.

Sanitary problems particularly weed management is a great constraint to sugar beet production and weeds may cause high yield losses (Rzozi et al., 1990). This paper presents the main results of investigations and experiments conducted in Tadla region to improve the weed management program by identifying mains weed species encountered in sugar beet field, studying the effect of weeds on sugar beet growth and estimating yield losses and determining the critical period of weed control and evaluating herbicide treatments.

2. Sugar beet weeds

2.1 Introduction

The sugar beet is an important strategic crop in the irrigated perimeter of Tadla. During these 5 last years, an annual surface of 12000 ha is emblaved by this crop. The average yield obtained in the region is approximately 45 to 50 T/ha, which is very low compared to the potential yield which would be of 100 T/ha. Several constraints of technical order are at the origin of this low production, among which the weak control of sanitary problems particularly weed management. In order to achieve a good control of weeds, these last must be well identified. Tanji and Boulet (1986) drew up a general floristic and biological inventory of these weeds in Tadla area (All crops included). The objective of this work was to study thoroughly this inventory in sugar beet.

2.2 Material and methods

2.2.1 Presentation of the study area

The plain of Tadla is located at the foot of the Middle Atlas Mountain (Center of Morocco) (Figure 1). This plain has an area of about 360,000 hectares. The altitude varies between 250 m and 500 m and an average of 400 m. According to Emberger climagram , the plain of Tadla has an arid climate with mild winter for the area north of the Oued Oum Er Rabia; winter to charge for the south as well as some of Beni Amir.

In general, natural vegetation is limited to the most degraded soils, the shallower and less suitable for agriculture are sheltered pastures. The average rainfall varies between 556 mm in Beni Mellal as maximum and 327 mm in Dar Ould Zidouh and is averaging 346.6 mm.These datas are decreasing because of climate change. Average monthly temperatures range from 10.2 ° C in January to 28 ° C in August. Minimum monthly temperatures range from 3.23 ° C in January and 18.5 ° C in August and the average maximum temperatures range from 17.8° C in January and 37.5°Cin August.

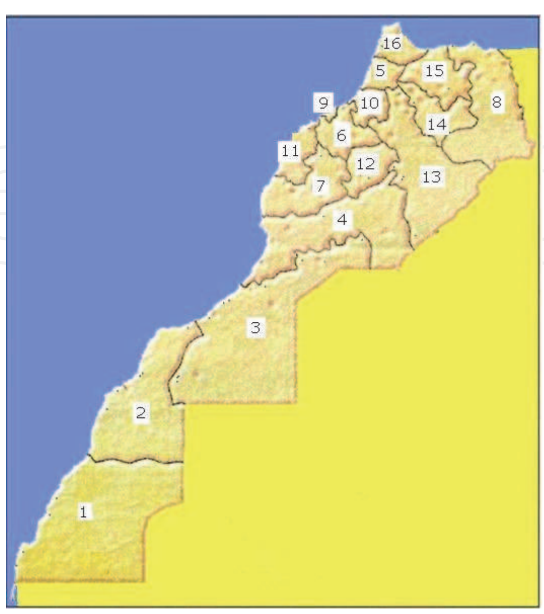

Fig. 1. Localisation of the studied region in Morocco map (12).

2.2.2 Prospecting and sampling

A total of 126 sugar beet fields were explored. Only fields not chemically treated and weedy full kept by farmers were prospected. A stratified sampling according to Gounot (1969) was established taking account of some factors mainly type of soil, rainfall and temperatures. Meanwhile, farmers were questioned about cultural practices and soil samples were taken in order to characterize soil texture and total calcium content.

The method of the "tower field" has been adopted to identify the weed species present (Maillet, 1981), for which an Abundance-Dominance Index (ADI) (+, 1, 2, 3, 4, 5) according to the scale of Montegut (Not dated) modified by Boulet et al. (1989) has been assigned. This index is as follows:

+: Very rare species (1 to 5 feet), virtually no recovery.
1: scarce species, recovery very low, irregular distribution
2: averagely abundant species, low recovery, irregular distribution
3: abundant species, covering less than 50%, regular distribution
4: abundant species, recovery of 50 to 75%, regular distribution
5: very abundant species, recovery from 75 to 100%, regular distribution

The agronomic importance of each species is judged based on its relative frequency and covering. The estimation of the average abundance of species during the reading was conducted assuming equivalences between the ADI and its average covering in percentage (Boulet et al, 1984). The methodology was as follows:

ADI	Covering	Average covering
5	75 – 100	87,5
4	50 – 75	65,5
3	25 - 50	37, 5
2	5 – 25	17, 5
1	1 – 5	5
+	< 1	1

These values allow calculating the average covering R of each species at reading time. The combination of this index, of the absolute frequency of species and their ethological type, allowed attribution of a "Partial Nuisibility Index" (PNI) to species (Bouhache et al, 1984).

PNI = (Sum of coverage/number of reading) x 100. The perennial species are underlined and only species with a frequency higher than 20% are taken in consideration.

Species encountered were identified by using some documents such as Flora Europea (Tutin et al., 1964- 1984), Catalogue des Plantes du Maroc (Jahandiez and Maire, 1931-34) and Mauvaises herbes des regions arides et semi arides du Maroc occidental (Tanji et al., 1988). The ethological type for each species was determined according to classification elaborated by Raunkiaer (1905). The biogeographical origin of weed species was derived from Quezel and Santa (1962-63) and Negre (1961-62) on flora investigations.

2.3 Results and discussion

2.3.1 Systematic aspect

A total of 144 weed species including volunteer wheat belonging to 30 botanical families (Table 1) were inventoried in the 162 sugar beet fields prospected. This number correspond respectively to 43,6% and 17,2% of the total weed flora of Tadla region (Tanji and Boulet, 1986) and of Central West Morocco (Boulet et al., 1989) and is relatively low compared to that observed in the Gharb region (Tanji et al., 1984), more important than that showed in Doukkala region (Bouhache and Ezzahiri, 1993) and similar to that found in Moulouya region (Taleb and Rzozi, 1993).

Dicotyledonous species are prevalent (118 species) and correspond to 81,9% of total encountered. Similar results are shown in other regions where sugar beet is grown. Six families dominated particularly the weed flora (Table 1): Asteraceae, poaceae fabaceae, brassicaceae apiaceae and caryophyllaceae. They provide 51.8% of the total. Representing 81 species , these six families are also dominant in sugar beet in Gharb region (Tanji et al.,1984), in cereals (Taleb and Maillet, 1994) and generally for the national flora (Bouhache and bouleT, 1984 and Ibn Tatou and Fennane, 1989). The most dominant family is the asteraceae, that is represented by 19 species, representing 13.2% of the weed flora found. The Asteraceae is also the richest family in species by about 20.000 species worldwide (Taleb, 1995)

2.3.2 Ethological aspect

According to RAUNKIAER classification, the 144 species surveyed belong to five ethological types (Table 2). The ethological spectrum is dominated by annuals (therophytes) with 119 species or 82,6% of the total. This data is similar to that obtained by the main regional botanical and floristic studies of sugar beet weed flora (Tanji et al., 1984; Bouhache and Ezzahiri, 1993; Taleb and Rzozi, 1993. The Geophytes follow with 17 species (11.8%), bisannuals (hemicryptophytes) with 5 species (3.5%) and the chamaephytes and others with 2 species (2.1%). The geophytes encountered are mainly monocotyledonous species with rhizomes, bulbs and tubers. The most important geophytes species inventoried are Convolvulus arvensis L., Solanum elaeagnifolium Cav. And Cynodon dactylon (L.) Pers. They cause serious problems to the crop.

2.3.3 Biogeographical distribution of species

The Mediterranean weed species (broadly defined) dominate the flora inventoried with 56.2%. This high rate of Mediterranean species confirms those of other authors (Bouhache and Boulet, 1984; Loudyi, 1985; Tanji and Boulet, 1986; Careme, 1990; Taleb, 1995; Wahbi, 1994; Bensellam, 1994) or for the entire Moroccan flora (about 2 / 3 according to Braun-Blanquet and Maire, 1924). European and eurasiatic species represent 5,5 and 4,9 % of the total. Cosmopolitan and sub- cosmopolitan are well represented (8,3%). This seems to be high comparatively to that reported by Bouhache and al., 1993. Concerning endemic species to north west of Africa, they are represented only by *Diplotaxis tenuissiliqua* Del., also reported by Tanji and Boulet (1986).

Famillies	Number of species	Contribution (%)	Ranking
Asteraceae	19	13,2	1
Poaceae	19	13,2	1
Fabaceae	18	12,5	3
Brassicaceae	9	6,2	4
Apiaceae	8	5,5	5
Caryophyllaceae	8	5,5	5
Amaranthaceae	6	4,2	7
Chenopodiaceae	5	3,5	8
Euphorbiaceae	4	2,8	9
Liliaceae	4	2,8	9
Papaveraceae	4	2,8	9
Plantaginaceae	4	2,8	9
Polygonaceae	4	2,8	9
Rubiaceae	4	2,8	9
Convolvulaceae	3	2,1	15
Malvaceae	3	2,1	15
Solanaceae	3	2,1	15
Lamiaceae	3	2,1	15
Boraginaceae	2	1,4	19
Geraniaceae	2	1,4	19
Ranunculaceae	2	1,4	19
Scrophulariaceae	2	1,4	19
Araceae	1	0,7	30
Cyperaceae	1	0,7	30
Iridaceae	1	0,7	30
Portulacaceaa	1	0,7	30
Primulaceae	1	0,7	30
Rhamnaceae	1	0,7	30
Urticaceae	1	0,7	30
Verbenaceae	1	0,7	30

Table 1. Specific contribution of botanical families encountered.

Biological type	%
Therophytes (Annuals)	82.6
Geophytes (Perennials)	11.9
Hemicryptophytes (Bisannuals)	3.4
Chamaephytes and nanophanerophytes	2.1

Table 2. Ethological aspect of sugar beet weed flora in Tadla.

2.3.4 Agronomic aspect

The number of weed species per Sugar beet field varied from 9 to 26 and averaged 17,5. It is relatively low compared to that reported at Doukkala region. The weed survey allowed

Species	**PNI**
Group 1: species with IPN>1000	
Lolium rigidum Gaudin.	1919
Phalaris brachystachys Link.	1530
Triticum aestivum L.	1209
Triticum durum L.	1112
Avena sterilis L.	1059
Convolvulus arvensis L.	1024
Group 2: species with 500<IPN<1000	
Lolium multiflorum Lam.	910
Cichorium endivia L.	787
Anagallis foemina Miller	768
Papaver rhoeas L.	700
Ridolfia segetum L.	672
Medicago polymorpha L.	651
Melilotus sulcata Desf.	642
Phalaris minor Retz.	640
Galium tricornitum Dandy	638
Chenopodium murale L.	635
Chenopodium album L.	590
Sonchus oleraceus L.	572
Lamium ampexicaule L.	570
Sinapis arvensis L.	528
Solanum elaeagnifolium Cav.	521
Malva parviflora L.	501
Fumaria parviflora Lam.	501
Group 3: species with 250<IPN<500	
Emex spinosa (L.) Campd.	401
Rumex pulcher L.	381
Chrysanthemum coronarium L.	325
Bromus rigidus L.	315
Calendula Arvensis L.	301
Vicia sativa L.	270
Chrysanthemum segetum L.	250
Group 4: species with IPN<250	
Polygonum aviculare L.	237
Phalaris paradoxa L.	220
Antirrhinum orontium L.	201
Reseda alba L.	187
Plantago afra L.	150
Scorpiurus vermiculatus L.	132
Vaccaria hispanica Med.	120
Lathyrus ochrus (L.) DG.	104
Cynodon dactylon (L.) Pers.	92

Table 3. Partial Nuisibility Index (PNI) of the most frequent weed species in sugar beet.

identifying 39 major weed species including volunteer wheat that are relatively frequent and cause serious problems and yield loss for the crop (table 3). These species were divided into four groups on the basis of their PNI.

Weeds belonging to group 1 are mainly monocotyledonous species such as *Lolium rigidum* Gaudin., *Phalaris brachystachys* Link., *Avena sterilis* L. And volunteer wheat (*Triticum aestivum* L. And *Triticum durum* L.). This later generally precede sugar beet in the plot. These species competes highly with sugar beet because of their relatively high covering and early emergence in the season. The perennial rhizomatous weed *Convolvulus arvensis* L. is also a dangerous species and it is very difficult to control because of its important vegetative multiplication.

Group 2 contain many species with PNI between 500 and 1000 that also could be noxious for the crop regarding their covering. These weeds are mainly dicotyledonous species such as *Anagallis foemina* Miller, *Papaver rhoeas* L., *Medicago polymorpha* L., *Chenopodium album* L., *Sinapis arvensis* L., *Galium tricornitum* Dandy. *Solanum elaeagnifolium* Cav. is deep rooted weed and a very troublesome species in all Tadla region.

Other species with relatively low covering (Groupe 3 and 4) are often encountered in sugar beet field but they are less competitive compared to those belonging to group 1 and 2: *Rumex pulcher* L., *Chrysanthemum coronarium* L., *Bromus rigidus* L., *Calendula Arvensis* L., *Vicia sativa* L., *Chrysanthemum segetum* L., *Reseda alba* L., *Plantago afra* L., *Scorpiurus vermiculatus* L., *Vaccaria hispanica* Med.

2.4 Conclusion

The sugar beet weed flora in Tadla region is much diversified. Effectively, 144 species belonging to 30 botanical families were encountered in the 126 field prospected. The most represented families are asteraceae, poaceae, fabaceae, bracassicaceae, apiaceae and caryophyllaceae. Therophytes (annuals) and dicotyledonous species dominate with 82,6% and 81,9 respectively. The floristic diversity vary from 9 to 26 species per field and it average 17, 5. The weed survey allowed identifying 39 major weed species including volunteer wheat that are relatively frequent and cause serious problems and significant yield losses for the crop.

3. Weed interference and critical period

3.1 Introduction

Weeds compete with crop plants for water, light nutrients and space and cause considerable yield losses. Integrate weed management (IWM) involves a combination of cultural, mechanical, biological, genetic and chemical methods for effective and economical weed control (Swanton and Weise, 1991). The principles of IWM should provide the foundation for developing optimum weed control systems and efficient use of herbicides. The critical period for weed control (CPWC) is a key component of an IWM program. Weeds are limiting factors in sugar beet production (Cooke and Scott, 1993). Integrated weed control management is necessary for minimizing weeds interference and maximizing the crop yield (Schweizer, 1983; Cooke and Scott, 1993).

The critical period of weed interference refers to the period during which a crop must be kept free of weeds in order to prevent yield loss. It represents the time interval falling between two separate components: (a) the minimum length of time after seeding that a crop must be kept weed-free so that later-emerging weeds do not reduce yield, and (b) the maximum length of time that weeds which emerge with the crop can remain before they become large enough to compete for growth resources (Radosevich and Holt, 1984; Zimdahl, 1988; Weaver *et al*., 1992; Baziramakenga and Leroux, 1994; Ghadiri, 1996).

Sugar beet can tolerate weeds until 2-8 weeks after emergence, depending on the weed species, planting date, the time of weed emergence relative to crop and environmental conditions (Cooke and Scott, 1993). The presence of weeds can decrease sugar beet yield by 90%. For example, a single presence of barnyardgrass *Echinochloa crus-galli* (L.) *Beauv.* plant per 1.5 m2 resulted in yield reduction of 5 to 15 % (Norris, 1996). The earliest date at which weeding could cease in sugar beet without significant yield loss has been shown to be between 4 and 12 weeks, depending on sowing date, rainfall and weed infestation (Link and Koch, 1984; Scott et aI., 1979; Singh et aI., 1996). Studies on the competitive effect of weeds in sugar beet have been numerous under temperate climates (Dawson, 1965; Farahbakhsh and Murphy, 1986; Schweizer and Dexter, 1987; Scott et aI., 1979; Zimdahl and Fertig, 1967). Continuous post-planting hand-weeding for 17 weeks and 15 weeks in 1990, and for 15 weeks and 12.5 weeks in 1991 were required to limit sugar beet root yield loss to 5% and 10%, respectively In Gharb region (Alaoui et al., 2003). Based on 10% loss of yield, the beginning of the critical period of weed control (CPWC) was 25 and 5 days after planting for the first year and the second year, respectively. On this basis, the end of the critical period of weed control was 78 days for the first year and 88 after planting for the second year (Salehi et al., 2006).

This research was conducted to study (i) the effect of weed competition on sugar beet growth parameters and (ii) determine the minimum period sugar beet should be kept weed-free after planting (CPWC) in the Tadla region to limit yield loss from late emerging weeds

3.2 Material and methods

3.2.1 Experimental site localization and characterization

Field experiment was conducted during two growth seasons 2003- 2004 and 2004-2005 at Afourer experimental station of the National Institute of Agricultural Research in Tadla region. The soil characteristic are as follows: 2.72 % organic matter, 11% sand, 37.2% silt, 51.6 % clay, and pH 8.1. Plots were plowed, disked three times and harrowed for seedbed preparation. Sugar beet cv. 'lydia', a mono germ variety, was seeded manually in a 2 cm deep in 70-cm wide rows with a spacing of 10 cm between seeds (population of 83,000 plants/ha) on October 15 in 2003 and November 25 in 2004.

Fertilization, irrigation and diseases and predators control were achieved in experimental plots according to those recommended by the sugar regional comity.

3.2.2 Competition duration

To determine the critical period of weed control in sugar beet, an experiment was conducted and consisting of 16 treatments. Weed free treatments included the removal of weeds at 4, 7, 9, 11, 13, 17 and 21 weeks after emergence (WAE) of sugar beet. In weed infested treatments, weeds were allowed to interfere with sugar beet crop 4, 7, 9, 11, 13, 17 and 21 weeks after emergence sugar beet crop. Two control treatments (full-season control of weeds and full-season interference of weeds) were also included. Individual plots consisted of 10 rows, each 10 m long.

3.2.3 Experimental design and statistical analysis

The experiment was a randomized complete block design with four replicates. Data on weeds and on sugar beet growth parameters and yield components were subjected to an analysis of variance using statistical STATITCF software. The means were compared using Fisher's protected LSD (α = 0.05).

3.2.4 Measurements

Weed density is not as reliable as biomass to assess weed interference in a crop (Scott et aI., 1979; Tomer et aI., 1991; Wilson and Peters, 1982), especially for species which have a high capacity to compensate for low densities through tillering and branching. Therefore, the impact of weed-free and weedy duration on weed growth and on crop growth and crop yield was assessed through weed dry weight. Weed dry weight were measured during the entire growing season for all individual plots. Four 0.5 m x 0.5m quadrates per plot were placed randomly over the plot. Weeds within the sampling area were removed by hand, taken to laboratory and dried at 60 C for 48 h to determine total weed dry weight. Sugar beet growth was assessed at the same time as weed sampling. Six sugar beet plants without root were taken randomly in plot but not on central rows that served for estimating yield. The number of leaf per plant, leaf area and dry matter was determined. Because of unavailability of an electronic leaf area meter, a graduated table was used for measuring leaf area. Sucrose percentage and the concentration of impurities (sodium, potassium, amino-N) were measured at the regional sugar factory.

3.3 Results and discussion

3.3.1 Effect of Weed free and weedy periods on weed dry matter

The dominant weeds observed in 2003 were volunteer wheat (ADI = 4), *Phalaris brachystachys* Link.(3), *Avena sterilis* L. (2), *Cichorium endivia* L. (4), *Papaver rhoeas* L. (3), *Ridolfia segetum* L. (3), *Sinapis arvensis* L. (3), and *Galium tricornitum* Dandy (2). With the exception of field bindweed (*Convolvulus arvensis* L.) (3), the same weed species were dominant in 2004. Weed free periods resulted in lower weed dry matter and weedy periods resulted in high weed dry matter (Figure 2). Maximum total weed dry weight generally decreased as weed-free duration was increased. The statistical analysis showed a highly significant difference (Not shown).

These findings are similar to those observed by Salehi et al. (2006), Rzozi (1993) and Alaoui et al. (2003). Weed growth was reduced drastically after a weed free duration greater than 17 WAE in both years. Same results were obtained for all the two years 2003 an 2004. For the later, weed dry matter was relatively lower because the later date of sowing results generally in low weeds density.

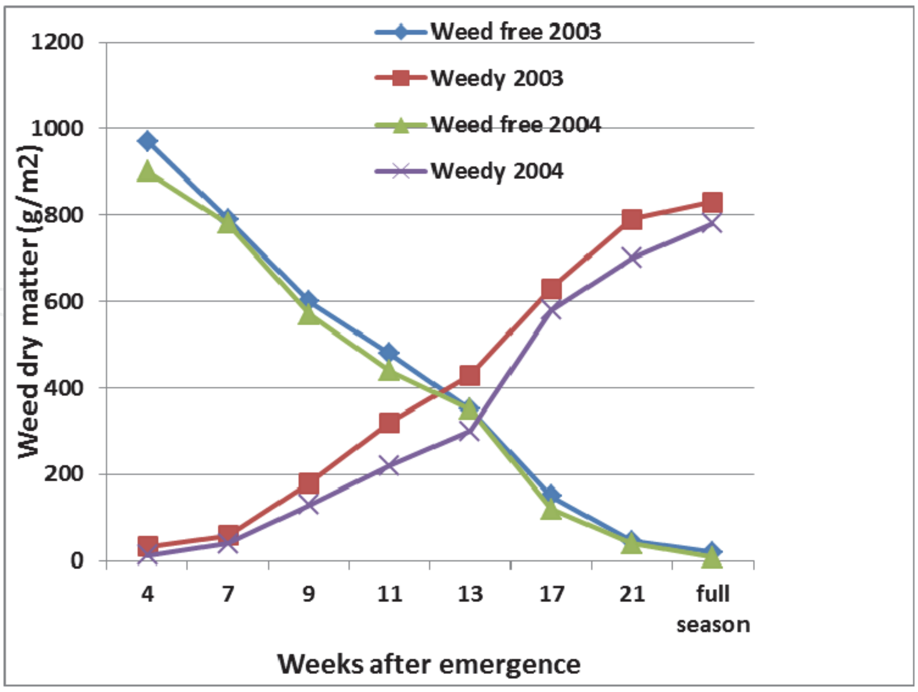

Fig. 2. Effect of competition duration on weed dry matter.

3.3.2 Effect of weed free and weedy periods on sugar beet growth parameters

All sugar beet growth parameters were affected by the presence of weeds. Effectively, the sugar beet leaf number decreased as weedy periods increased and in contrast it increased as weed free periods increased (Figure 3). Also, the leaf area decreased as weedy periods increased. This parameter was highly significantly reduced because of the important competitive effect of weeds. (Figure 4). The crop leaf dry matter was also significantly reduced by the weed competitive effect. The longer the weedy period the lower sugar beet dry matter. The later increased as the weed free period increased (Figure 5). These results confirm those of Alaoui et al. (2003) reporting that the leaf area and the other growth parameters are vigorously decreased by the competitive effect of weeds.

3.3.3 Effect of weed free and weedy periods on sugar beet yield, on sugar yield and sugar content

Weed infestation reduced root yield in all treatments. The presence of weeds during the entire growing season decreased root yield by 97.6 % and 68.9 % in 2003 and 2004, respectively, as compared to full season weed free check. Although sugar content did not show any significant difference between various treatments in both years, weed infestation decreased sugar yield, their corresponding yields decreased considerably in infested treatments. For example, season-long weed infestation decreased sugar yield by 89.8% and 81.1 % in 2003 and 2004, respectively, as compared to weed free check (data not shown). The concentration of sugar beet impurities such as potassium, sodium and amino nitrogen were not affected by weed competition (data not shown).

In most years in Morocco, weeds can cause more than 75% yield reduction (Rzozi, unpublished data; Rzozi et al., 1990). Such reductions indicate complete crop failure because small sugar beet roots produced under severe weed competition cannot be processed. In other countries, weeds also seriously suppress sugar beet yield (Schweizer and Dexter, 1987).

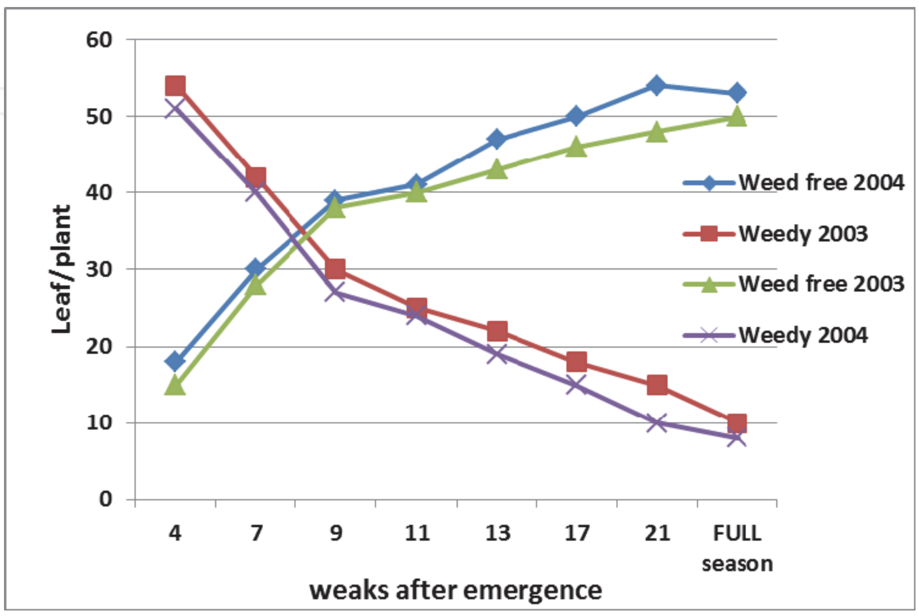

Fig. 3. Effect of weeds on sugar beet leaf number.

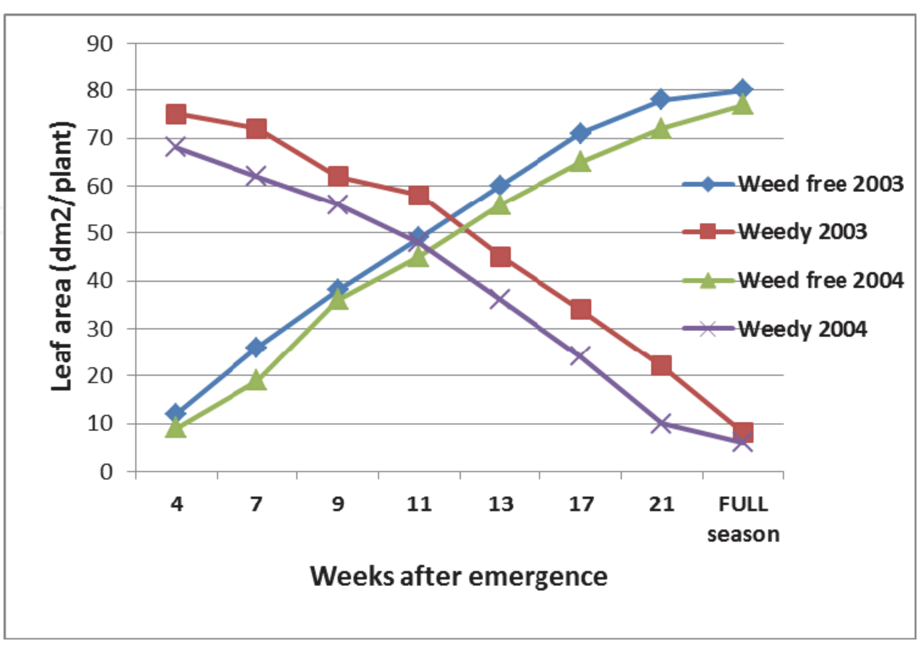

Fig. 4. Effect of weeds on sugar beet leaf surface.

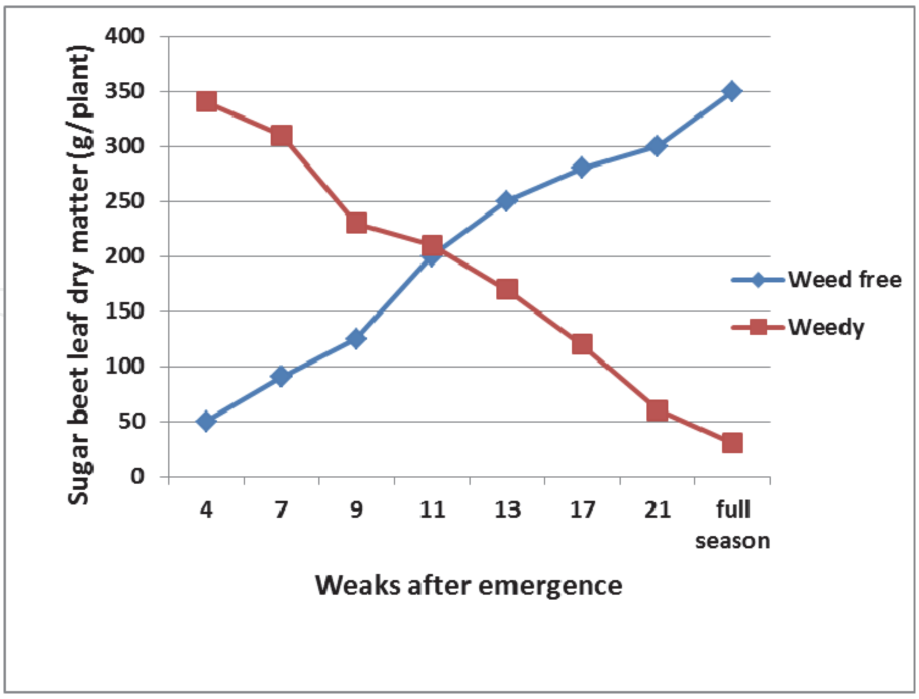

Fig. 5. Effect of weeds on sugar beet leaf dry matter.

3.3.4 Critical period of weed control

Weed interference caused a sharp decline in sugar beet root yield in both years (Figure 6 and 7). Based on 10 % permissible decrease in root yield, weeding should start from 4 WAE and 7 WAE in 2003 and 2004, respectively (Figure 6 and 7). For the given 10% root yield reduction, weed control should be continued until 15 WAE and 12 WAE in 2003 and 2004, respectively (Figure 5 and 6). Weed interference caused a sharp decline in sugar yield (data not shown). Based on 10 % permissible decrease in root yield, weeding should start from 3.5 WAE and 7 WAE and must be continued until 15 WAE and 11 WAE in 2003 and 2004 respectively.

The results show that the critical period begins earlier in 2003 and its duration is longer comparatively to that observed in 2004 which is shorter and begins relatively later. This may be due to date of sowing. Effectively, in 2003, sugar beet was sown October 15 and this allows to many weed species, particularly gramineous including volunteer wheat, to germinate and emerge in great number and vigorously at the same time of the crop germination and emergence. In 2004, sugar beet was sown 25 November. At this time, a great number of weed species (mainly gramineous) has germinated and emerged from soil and destructed during the seedbed preparation.

Emergence time of weeds influences the critical period of weed control (Zimdahl, 1987; Weaver *et al.*, 1992; Mesbah *et al.*, 1994; Ghadiri, 1996). In Shahrekord, sugar beet is planted in May and June; this delay in seedbed preparation and planting may lead to earlier germination of weeds over the sugar beet crop. Therefore, critical period of weed control starts earlier and its duration is longer. At early growth stages, sugar beet has a low competitive ability against weeds; as a result critical period would start sooner. In 2003, presence of weeds for the entire growing season reduced root yield by 97.6% relative to weed free control. In 2004, the reduction was 68.6 %. A similar 71% root yield reduction was also observed by Shahbazi and Rashed Mohassel (2000). Dawson (1977) showed that annual weeds that germinate during a 2-week period after planting or a 4-week period after two-leaf stage in sugar beet reduce root yield by 26 to 100%. Therefore, effective control of weeds at early stages seems to be more important than that of later developed stages. The closure of crop canopy at later growth stages suppresses the late-emerging weeds. The increased period of weed competition reduces the photosynthesis and crop growth

(Zimdahl, 1987; Ghadiri, 1996). Longer presence of weeds caused more use of environmental resources (light, water, and nutrients) and more accumulation of dry matter in weeds, making the critical period longer and, therefore reducing root and white sugar yield of the sugar beet crop.

3.4 Conclusion

A field experiment was conducted during two growing seasons 2003/2004 and 2004/2005 to assess the effect of weeds on sugar beet growth parameters and sugar beet yield and to determine the critical period of weed control (CPWC). Weed free treatments and weed infested treatments included the removal (or not) of weeds at 4, 7, 9, 11, 13, 17 and 21 weeks after emergence of sugar beet. Dry matter of weed, sugar beet leaves/plant, sugar beet leaf area and sugar beet dry weight was measured during all growing season. Weed free periods resulted in lower weed dry matter and weedy periods resulted in high weed dry matter. Maximum total weed dry weight generally decreased as weed-free duration was increased. The presence of weeds during the entire growing season decreased root yield by 97.6 % and 68.9 % in 2003 and 2004, respectively. All crop growth parameters were significantly reduced by weed infestation.

The critical period of weed control began at 4 and 7 weeks after sugar beet emergence (WAE) and continued until 15 and 12 WAE in 2003/2004 and 2004/2005 respectively depending on sowing period. It was concluded that the CPWC is longer in 2003/2004 than in 2004/2005.

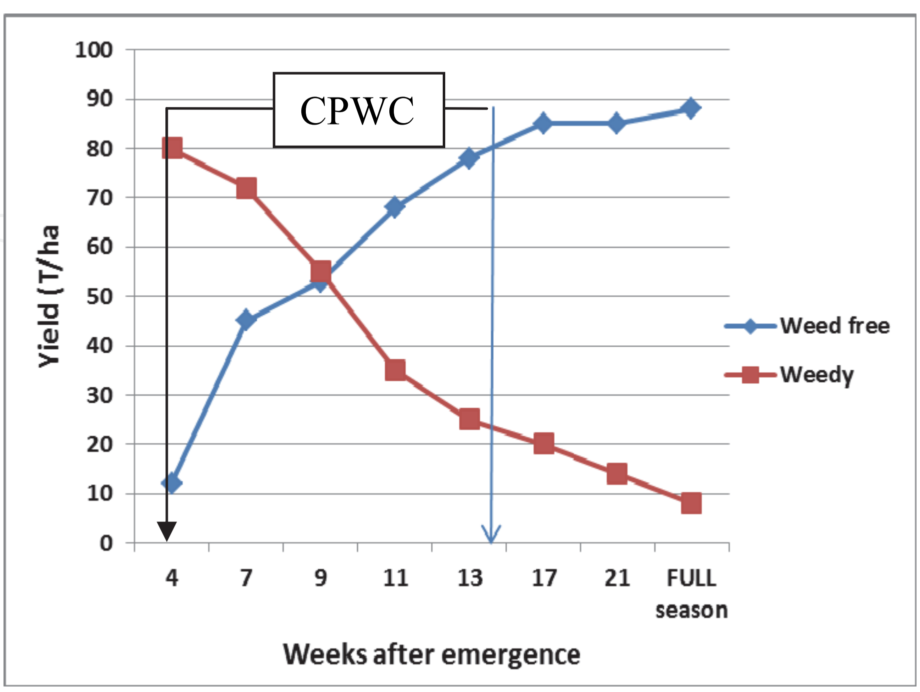

Fig. 6. Critical period of weed control (2003/2004).

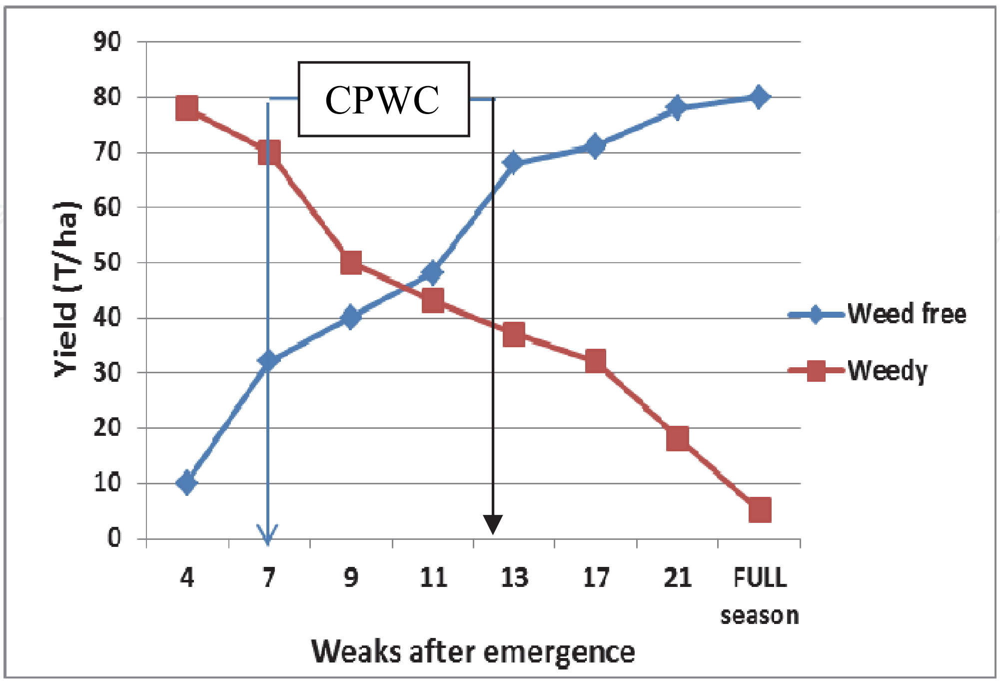

Fig. 7. Critical period of weed control (2004/2005).

4. Chemical control of sugar beet weeds

4.1 Introduction

In the area of Tadla, sugar beet is regarded as an important crop. Weeds constitute a great constraint to crop production improvement and cause important yield losses (Rzozi and al., 1990). The farmers do not use herbicides efficiently. Generally, only one herbicide is applied and the results are not satisfactory (Baye et al, 2004). This work aims to develop a chemical weed control program by evaluating the effectiveness of some herbicide treatments.

4.2 Material and methods

4.2.1 Field experiment localization

A field experiment was conducted during the two sugar beet growing seasons 2003/2004 and 2004/2005 in three location Fqih Ben Salah, Afourer and Deroua to assess the efficacy of some herbicide treatments. These locations were chosen in order to have diversified weed flora and then have maximum information about herbicide activity spectrum.

4.2.2 Herbicides and herbicide treatments studied

The main and important herbicides homologated on sugar beet and registered in Morocco such as ethofumesat, desmedipham, phenmedipham, metamitron, triflusulfuron methyl and lenacil were experimented (Table 4). Thes active ingredients were tested either alone or in mixture (Table 5). A hand weeding taked place for all treatments when it was necessary.

4.2.3 Observations on weeds

The importance of weeds encountered in field experiments was estimated according to the Abundance – Dominance-Index (ADI).

4.2.4 Evaluation of herbicide efficacy

Weed dry weight were measured during at 60 days after treatments (DAT) for all individual plots. Four 0.5 m x 0.5m quadrates per plot were placed randomly over the plot. Weeds within the sampling area were removed by hand, taken to laboratory and dried at 60° C for 48 h to determine total weed dry weight. The efficacy in percentage (%) for each treatment is calculated comparing its dry matter to that of the check.

4.2.5 Observations on the crop

The sugar beet yield was estimated on the two central rows at harvest. Sucrose percentage and the concentration of impurities (sodium, potassium, amino-N) were measured at the regional sugar factory.

4.2.6 Experimental design and statistical analysis

The experiment was a randomized complete block design with four replicates. Individual plots were 4m x 8m size. Data on efficacy (%) were first transformed to Arc Sin% if necessary. Sugar beet yield and efficacy data were subjected to an analysis of variance using statistical STATITCF software. The means were compared using Fisher's protected LSD (α = 0.05).

Commercial product	**Active ingredient**
Tramat Combi	30 % ethofumesat + 12 % lenacil
Betanal Progress	16 g/l desmedipham + 62 g/l phenmedipham + 128 g/l ethofumesat
Goltix	70 % metamitron
Safari	70 % triflusulfuron methyl
Venzar	80 % lenacil
Fusilad Super	125 g/l Fluazifop p-butyl

Table 4. herbicides tested.

4.3 Results and discussion

4.3.1 Importance of weed flora

In Fqih Ben Salah location, weed flora is dominated by gramineous mainly volunteer wheat. Some dicotyledonous species such as *Malva parviflora, Medicago polymorpha, Emex spinosa* and *fumaria parviflora* are important (Table 6). In Deroua location, infestation by gramineous was low and *cichorium endivia*, *Sinapis arvensis* and *convolvulus arvensis* were dominant in 2003/2004 and *Rumex pulcher*, *Papaver rhoas* and *Ridolfia segetum* dominated the weed flora in 2004/2005. Concerning Afourer, C*ichorium endivia*, *Sinapis arvensis, Polygonum aviculare, Lamium amplexicaule and Ridolfia segetum* were the most important species in both two growing season.

4.3.2 Efficacy of the herbicide treatments

Generally, fluazifop- p- butyl (Fusilade Super) achieved a good gramineous control (data not showed). However, it is important to mention that some ray grass (*Lolium* spp) population had recently developed resistance to this herbicide.

Treatments	Herbicide treatments tested
T1	Tramat Combi (3,5l/ha) in post sowing preemergence
T2	Goltix (5kg/ha) applied in post sowing preemergence
T3	Goltix (5kg/ha) in 2 applications (2,5 + 2,5) kg/ha post emergence (2 true leaves stage)
T4	Safari (60g/ha) in 2 applications (30+30) g/ha) post emergence (2 true leaves stage)
T5	Betanal Progress (5l/ha) in 2 applications (3 + 2) l/ha g/ha) post emergence (2 true leaves stage)
T6	(Safari (30g/ha) + Venzar (200g/ha) applied twice post emergence (2 true leaves stage)
T7	(Betanal Progress(1,25l/ha) + Safari (30g/ha)) applied twice post emergence (2 true leaves stage)
T8	(Betanal Progress (1,25l/ha) + Goltix (1kg/ha)) applied twice post emergence (2 true leaves stage)
T9	(Goltix (1kg/ha) + Safari (30g/ha) applied twice post emergence (2 leaf stage)
T10	(Betanal Progress (1L/ha) + Goltix (300g/ha) + Venzar (100g/ha)) applied twice post emergence (2 true leaves stage)
T11	(Betanal Progress (0,8L/ha) + Safari (30g/ha) + Goltix (300g/ha) + Venzar (100g/ha)) applied twice post emergence (2 true leaves stage)
T12	Hand weeding (Three times in the season)
T13	Check (Not treated)

Table 5. Herbicides treatments experimented.

In order to control gramineous species, all first post emergence application are mixed with Fusilade Super (1l/ha); an oil concentrate adjuvant (Seppic at 1/ha) is adjusted to the two application to obtain satisfactory activity. The second application is made 10 days after the first.

Concerning post sowing preemergence application treatments, Tramat combi (T1) provided good efficacy (90 % and more) and protected then the crop for a long period more than 2 months (Table 7). This allowed to sugar beet to grow vigorously. The treatment controlled both dicotyledonous and monocotyledonous species except *Emex spinosa* that showed some tolerance to this herbicide. The other treatment applied preemergence (T2) showed not satisfactory with efficacy lower than 68 %. This herbicide did not control monocotyledonous (volunteer wheat included) and many other dicotyledonous species such as *Medicago polymorpha and Melilotus sulcata.*

For post emergence applications, it was noted that when treatments were applied alone (not mixed), the efficacy was not satisfactory. Effectively, efficacy was generally below 70 % except T5 in 2004/2005 at Deroua (Table 7). In this case, the percent control is above 80 %.

This difference in efficacy is explained mainly by the herbicide activity of each one. Safari (T4) provides low control against *Papaver rhoeas, Chenopodium album, Anagallis foemina, stellaria media, Cichorium endivia and Fumaria parviflora.* In contrast, it achieves good control against many other important species particularly malvaceae, *Malva parviflora*, apiaceae such as *Ridolfia segetum* and *Ammi majus* and brassicaceae maily *Sinapis arvensis.* Goltix (T3) did not control apiaceae, malvaceae and other species; however, it provides good control of polygonaceae such as *Rumex pulcher* and *Emex spinosa.* Betanal Progress presented the most large herbicide activity spectrum and controlled great number of species even applied alone in some times. This is the case of Deroua in 2003/2004. The efficacy obtained is 82%.

Generally, treatments achieved good efficacy when applied in tank mixtures than when applied individually alone because of their complementarily in eliminating maximum weed species. So, this must be taken in consideration in a weed chemical management program.

	Fqih Ben Salah		**Afourer**		**Deroua**	
Species	**2003/04**	**2004/05**	**2003/04**	**2004/05**	**2003/04**	**2004/05**
Volunteer wheat	4	3	1	2	2	2
Phalaris brachystachys	1	3	3	3	2	2
Lolium rigidum	3	2	2	1	1	1
Avena sterilis	2	2	1	2	2	2
Bromus rigidus	+	+	+	+	+	1
Malava parviflora	4	3	+	+	+	1
Emex spinosa	3	1	2	+	+	2
Rumex pulcher	+	+	1	1	2	4
Anagallis foemina	1	4	3	3	+	2
Chenopodium album	2	3	3	1	1	2
Fumaria parviflora	3	3	1	1	+	1
Cichorium endivia	+	2	4	4	4	2
Convolvulus arvensis	+	1	2	3	3	3
Sinapis arvensis	1	1	4	4	1	2
Sonchus oleraceus	1	1	2	2	1	2
Polygonum aviculare	1	+	4	3	+	1
Lamium amplexicaule	1	+	4	3	1	2
Medicago polymorpha	4	+	3	2	1	2
Melilotus sulcata	2	1	2	+	1	1
Papaver rhoeas	2	+	3	2	+	4
Ridolfia segetum	+	+	2	4	1	3
Ammi majus	-	+	+	+	+	+
Stellaria media	-	+	+	+	+	3
Veronica polita	-	+	+	1	-	1
Torilis nodosa	-	-	+	+	-	-
Euphorbia exigua	-	-	+	+	-	-
Galium aparine	-	-	1	1	-	1
Capsella bursa-pastoris	-	-	+	+	2	3

Table 6. Weed species encountered in field experiments.

4.3.3 Effect of herbicide treatments on sugar beet yield

Weed presence in sugar beet during all season caused yield losses between 86 and 93% following the nature of weed flora and the location. Herbicide treatments did not affect the sugar content percentage (Data not showed). Sugar beet yield was significantly affected by the herbicide treatments (Table 8). The post sowing preemergence treatment (Tramat Combi) achieved a satisfactory yield averaging 75 T/ha. This is due to its good weed control achievement during a long period. When used in tank mixtures (particularly 3 and 4 products), herbicide treatments provide high yields (Table 8). It is important to mention that weed chemical treatment alone is generally not sufficient to provide good root sugar beet production and it must be followed by other weed control methods such as mechanical, cultivation and hand weeding.

Treatments	Fqih Ben Salah		Afourer		Deroua	
	2003/04	2004/05	2003/04	2004/05	2003/04	2004/05
T1	89.5a	86a	87.3a	86.9a	90.1a	92.6a
T2	62c	60.3c	65c	65.9b	64bc	68.4b
T3	69.3b	60.7c	65.2c	66.8b	69.5b	65.2bc
T4	65.4bc	69b	63.5c	65.2b	61.4c	50.1d
T5	72b	79ab	75b	70b	82a	62.9c
T6	75b	72.2b	65c	69b	72.6b	62c
T7	84a	86.4a	87.8a	85.7a	86.9a	66bc
T8	75.1b	79b	76b	62b	80.1a	74.1b
T9	72b	75.6b	69.3c	67b	65b	72.b
T10	75b	77b	62c	60b	69b	75b
T11	88.2a	86.7a	88.1a	86.3a	88.6a	80.6a
T12	70b	73b	74b	69b	73b	65bc

Means within columns followed by different letters are significantly different at α = 0.05.

Table 7. Efficacy of herbicide treatments (%) at 60 DAT.

	Fqih Ben Salah		Afourer		Deroua	
Treatments	**2003/04**	**2004/05**	**2003/04**	**2004/05**	**2003/04**	**2004/05**
T1	74a	72.9a	75a	74.6a	78a	80.2a
T2	52.3c	53.6c	51c	49c	53.3bc	51.6c
T3	54.3bc	51c	50.9c	52.3c	53.4bc	50.3c
T4	52c	53.2b	52.6c	51c	50c	46c
T5	60b	62b	60.3b	59.2b	68a	51c
T6	62.1b	61.4b	54bc	58bc	60.6b	50.6c
T7	69a	70.5a	71.2a	72a	71.9a	73.2a
T8	61.6b	63b	64.5b	65.1b	69a	61b
T9	53c	60b	51c	50c	49c	52.3c
T10	60.8b	62.6b	57bc	55.4c	59b	61b
T11	70.2a	71.3a	72.6a	71.9a	73.3a	72.8a
T12	49.8c	50.9c	51c	52c	50.2c	51.9c
T13	7.2d	5d	3.9d	8d	4.8d	6.3d

Means within columns followed by different letters are significantly different at $\alpha = 0.05$.

Table 8. Effect of herbicide treatments on sugar beet yield.

Many studies relative to sugar beet weed chemical control were achieved in Morocco and other counties. Bensellam et al. (1993) reported that phenmediham + pyrazone achieved good control of weeds in sugar beet. Rzozi et al. (1990) found that nor metamitrone followed by phenmedipham neither chloridazone applied preemergence gave good efficacy. El Antri (2002) reported that triflusulfuron methyl + lenacil + clopyralid achieved good control of weeds in sugar beet. El Ghrasli and Allali (2002) estimated that farmers in Gharb region could use Safari, Goltix, Betanal and Venzar to control weeds in sugar beet. The pre sowing and preemergence herbicides: Tramat Combi and Goltix and the post emergence safari, Goltix, Betanal Progress and Venzar are widely used in France (Anonymous, 1999) and in USA (Stachler, 2011).

4.4 Conclusion

A field experiment was conducted during two growing seasons 2003/2004 and 2004/2005 in three locations in Tadla region to evaluate the effectiveness of some herbicides treatments. The main and important herbicides homologated on sugar beet and registered in Morocco such as ethofumesat, desmedipham, phenmedipham, metamitron, triflusulfuron methyl and lenacil were experimented individualy alone or in tank mixtures.

Tramat combi (Ethofumesate + lenacil) applied post sowing preemergence provided good efficacy (90 % and more) and protected then the crop for a long period more than 2 months.

Generally when applied post emergence, herbicides ethofumesate, metamitron, triflusulfuron methyl, phenmedipham, desmedioham and lenacil achieved good efficacy in tank mixtures than applied individually alone because they are complementarily in eliminating maximum weed species. So, this must be taken in consideration in a weed chemical management program. These herbicide treatments allow to crop to grow without weed competitiveness nearly until the end of the critical period and are often followed by a mechanical cultivation or a hand hoeing.

5. General conclusion

In Morocco, sugar beet is an important strategic crop. It is planted from September through June - July. Yield obtained by farmers, averaging 50 T/ha, is significantly below the request potential that would be 90 to 100 T/ha. Many factors contribute to low sugar beet production. Poor stand establishment, inadequate weed control, inadequate insect control and inadequate nitrogen fertilization are the main causes of low tonnage and poor quality sugar beet in Morocco.

This paper presents the main results of investigations and experiments conducted in Tadla region to improve the weed management program by identifying mains weed species encountered in sugar beet field, studiying the effect of weeds on sugar beet growth and estimating yield losses and determining the critical period of weed control and evaluating herbicide treatments.

One hundred twenty six (126) fields of sugar beet were surveyed by stratified sampling in Tadla region (Center of Morocco). In total, 144 weed species belonging to 30 botanical families were recorded. Six among them asteraceae, poaceae, fabaceae, brassicaceae, apiaceae and caryophyllaceae account 81 species (56,1% of total species). Dicotyledonous (81,9%), annuals (82,6%) and the Mediterranean floristic element (56,2%) were predominant and characterized the weed flora. The agronomic study made it possible to distinguish 24 species and volunteer wheat causing appreciable problems to the crop. Statistical analysis using soil-climatic factors allowed distinguishing four ecologic groups.

To determine the critical period of weed control in sugar beet, an experiment was conducted and consisting of 16 treatments. Weed free treatments included the removal of weeds at 4, 7, 9, 11, 13, 17 and 21 weeks after emergence (WAE) of sugar beet. In weed infested treatments, weeds were allowed to interfere with sugar beet crop 4, 7, 9, 11, 13, 17 and 21 weeks after emergence sugar beet crop. Weed infestation reduced root yield in all treatments. The presence of weeds during the entire growing season decreased root yield by 97.6 % and 68.9 % in 2003 and 2004, respectively. Based on 10 % permissible decrease in root yield, weeding should start from 4 WAE and 7 WAE in 2003 and 2004, respectively. For the given 10% root yield reduction, weed control should be continued until 15 WAE and 12 WAE in 2003 and 2004. The results show that the critical period begins earlier in 2003 and its duration is longer (77 days) comparatively to that observed in 2004 which is shorter (35 days) and begins relatively later.

A field experiment was conducted during two sugar beet growing seasons 2003/2004 and 2004/2005 in three locations to assess the efficacy of some herbicide treatments. These locations were chosen in order to have diversified weed flora and then have maximum information about herbicide activity spectrum. Concerning post sowing preemergence application treatments, Tramat combi (T1) provided good efficacy (90 % and more) and protected then the crop for a long period more than 2 months. This allowed to sugar beet to grow vigorously. The treatment controlled both dicotyledonous and monocotyledonous species. For post emergence applications, it was noted that when treatments were applied alone (not mixed), the efficacy was not satisfactory. Generally, herbicides (ethofumesate, metamitron, triflusulfuron methyl, phenmedipham, desmedioham and lenacil) achieved good efficacy when applied in tank mixtures than when applied individually alone because they are complementarily in eliminating maximum weed species. So, this must be taken in consideration in a weed chemical management program. These herbicide treatments allow to crop to grow within weed competitiveness nearly until the end of the critical period and are often followed by a mechanical cultivation or a hand hoeing.

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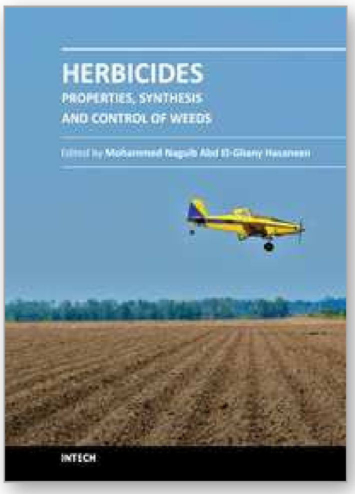

Herbicides - Properties, Synthesis and Control of Weeds
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This book is divided into two sections namely: synthesis and properties of herbicides and herbicidal control of weeds. Chapters 1 to 11 deal with the study of different synthetic pathways of certain herbicides and the physical and chemical properties of other synthesized herbicides. The other 14 chapters (12-25) discussed the different methods by which each herbicide controls specific weed population. The overall purpose of the book, is to show properties and characterization of herbicides, the physical and chemical properties of selected types of herbicides, and the influence of certain herbicides on soil physical and chemical properties on microflora. In addition, an evaluation of the degree of contamination of either soils and/or crops by herbicides is discussed alongside an investigation into the performance and photochemistry of herbicides and the fate of excess herbicides in soils and field crops.