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# Optimizing the Integrated Weed Management in Sugar Beet Field with the Aim of reducing Herbicides Application

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**ABSTRACT**

*Field experiment was conducted at Iranian Plant Protection Research farm in karaj during 2009 to evaluate the effects of diffrent planting patterns, times of mechanical control and herbicides application on weeds density and biomass in sugar beet farms. The experimental design was split–split plot based on randomized complete block design (RCBD) with four replications. Planting pattern considered as main–plot in three levels including single row planting with 50 cm row width, single row planting with 60 cm row width and twin row planting with 60 cm row width, time of mechanical control in three levels as sub–plot including mechanical weed control at 4–6 leaves stage, 10–12 leaves stage and 14–16 leaves stage (of sugar beet), and herbicides as sub–sub plot in two levels including metamitron plus combination of phenmedipham + desmedipham + ethofumesat and triflusulfuron–metil plus combination of phenmedipham + desmedipham + ethofumesat. Results of this study showed that times of mechanical weed control and herbicide application had significant effect on density and biomass of weeds. In most cases, planting pattern had appropiriate effect on weeds biomass reducthion that best results were achived in twin row planting 60 cm. Furthermore, Best results were achived in mechanical weed control at 4–6 leaves stage of sugar beet that had the most reduction on weeds density and biomass. metamitron plus combination of phenmedipham + desmedipham + ethofumesat had also the best effect on weeds density and biomass. Finally, sugar beet yield components were not affected by treatments as appropiriate as weeds control.*

**Key Words**: herbicide; mechanical control; planting pattern

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## INTRODUCTION

Cultural and mechanical methods are the most important non chemical weed management techniques than eliminate weeds with low cost [1, 2, 5, 8, 10, 14]. Cultivating the soil by chisel plough, can burry weeds in soil to some extent but sweep plow usually brings up the soil vertically. These blades cut the roots of large weeds, uproot smaller weeds and burry them under the soil [7]. An experiment showed that a hand weeding 10–20 weeks after planting sugar beet can keep the field clean of weed until the harvest time [9]. Changing the population of crop by changing the rows spacing sill also reduce weeds growth [7]. In an experiment, researchers tested this and found out that when planting pattern is rectangular, weeds will grow more and occupy more land [12]. It is clear that reduction of rows spacing will increase crop competition ability, and reduce amount of sun light transmitted to soil surface so weeds germination and growth will decrease [1]. To study this, researchers conducted an experiment and concluded that twin–row planting pattern of peanut will help to control weeds better than in single–row pattern [3]. Brecke and Stephanson (2006) also attest that twin–row planting pattern of peanut is better than single–row [2]. Another experiment showed that twin–row pattern can reduce the density of *Amaranthus retroflexus* (66%), *Setaria viridis* (80%) and *Cyperus rotundus* (73%) compared with single row [16]. Other experiments of peanut resulted that total weeds density was lower in row spacing of 30 cm than in 91 cm [4, 15]. In a sugar beet field, Hemmatzadeh et al. (2007) observed that twin–row planting pattern reduced weeds biomass 85–95% compared with single–row [6]. Finally, the objective of this experiment was to integrate non chemical weed management techniques (mechanical control and planting pattern) with herbicides in order to optimize weed management in sugar beet and to reduce application of herbicides and environmental contamination

## MATERIALS AND METHODS

This experiment was conducted in 2009 at the research farm of Iranian plant protection research institute, located in Karaj. Experimental design was split–split plot in the form of randomized complete block with four replications. Planting pattern was a main plot in three levels: single row 50 cm width, single row 60 cm and twin row 60 cm width. Sub plots were time of mechanical control in three levels: mechanical weed control at 4–6, 10–12 and 14–16 sugar beet leaves stages between rows and sub sub–plots were herbicides: metamitron (preemergence) plus mixture of phenmedipham + desmedipham + ethofumesat (2–4 leaves stage) and triflusulfuron–methyl (cotyledon stage) plus mixture of phenmedipham + desmedipham + ethofumesat (2–4 leaves stage). Herbicides were applied on the rows by a knapsack sprayer according to the recommended dose: triflusulfuron–methyl 30 g $ha^{-1}$, phenmedipham + desmedipham + ethofumesat 4 Li $ha^{-1}$ and metamitron 4 kg $ha^{-1}$.

After preparing the field with the conventional method, sugar beet (var: Rasul) was planted at 100000 plants $ha^{-1}$ in both single and twin row system. As a result, sugar beat was planted with 20, 16.6 and 33.3 cm in single row 50 cm, single row 60 cm and twin row 60 cm width respectively.

Weeds density and biomass were studied 30 days after herbicides application. To do this, a 50 × 50 cm quadrate was installed in each plot and number of weeds was counted before spraying and 30 days after spraying. To measure the biomass of weeds, 30 days after spraying weeds in quadrates were harvested and oven dried at 75$^{o}$C. To control grass weeds, Haloxyphop–R methyl ster was used 1 Li $ha^{-1}$ in all plots in grasses 2–5 leaves stage. Finally data were analyzed using SAS 9.1 [13] and means were compared by Duncans multiple range test at $p \leq 0.01$ and 0.05.

## RESULTS

**Weeds density**. Results showed that planting pattern has had significant effect only on *Amaranthus retroflexus* at $p \leq 0.01$ (Table 1). Herbicides had also significant effect on *A. retroflexus* and *Chenopodium album* ($p \leq 0.01$) but times of mechanical control showed no significant effect on studied weeds. Moreover, none of the treatments could affect *Datura stramonium*. Mean comparison showed that different types of planting patterns have affected density of *A. retroflexus* significantly in the way that lowest density of this weed (23.5 plant $m^{2-1}$) was in single–row 60 cm. different herbicide treatments had also significant effect on *A. retroflexus* and *C. album*. Metamitron plus combination of phenmedipham + desmedipham + ethofumesat controlled these two weeds the best (23 and 13.2 plants $m^{2-1}$, respectively) and triflusulfuron–methyl plus combination of phenmedipham + desmedipham + ethofumesat controlled them the worst (35.3 and 33.3 plants $m^{2-1}$, respectively). No significant difference was observed in times of mechanical control (Table 1).

Interactions of planting pattern × time of mechanical control and planting pattern × herbicide and also planting pattern × time of mechanical control × herbicide was significant on density of *A. retroflexus* and *C. album* but interaction of time of mechanical control × herbicide was significant only on density of *A. retroflexus*. Mean comparison of interaction of planting pattern × time of mechanical control showed that single–row 50 cm × mechanical control at 10–20 leaves stage (sugar beet) is the best treatment for controlling *A. retroflexus* (18.8 plants $m^{2-1}$) and twin–row 60 cm × mechanical control at 10–12 leaves stage is the best treatment for controlling *C. album* (14.8 plants $m^{2-1}$) (Table 4). Also results indicate that interaction of single–row 50 cm × metamitron plus combination of phenmedipham + desmedipham + ethofumesat has had the most controlling effect on *A. retroflexus* (11.6 plants $m^{2-1}$) and *C. album* (10 plants $m^{2-1}$) (Table 5). Furthermore, study of the interaction of mechanical control × herbicide shows that the lowest density of *A. retroflexus* (14.8 plants $m^{2-1}$) is achieved in mechanical control at 4–6 leaves stage × metamitron plus combination of phenmedipham + desmedipham + ethofumesat and the highest density of the weed is achieved in mechanical control at 14–16 leaves stage × triflusulfuron–methyl plus combination of phenmedipham + desmedipham + ethofumesat (Table 6). Generally, mean comparison of the triple interaction of planting pattern × time of mechanical control × herbicide demonstrates that single–row 50 cm × mechanical control at 4–6 leaves stage × metamitron plus combination of phenmedipham + desmedipham + ethofumesat has been the most effective treatment and has left only 8.8 *A. retroflexus* and 8 *C. album* in square meter (Table 7).

**Table 1. Mean comparison of main effects of treatments on weeds density (plant $m^{2-1}$).**

| Treatments | *A. retroflexus* | *C. Album* | *D. stramonium* |
|---|---|---|---|
| **Planting pattern** | | | |
| single row spaced 50 cm apart | 23.5 c | 22.8 a | 13.6 a |
| single row spaced 60 cm apart | 35.3 a | 24.1 a | 13.5 a |
| twin row spaced 60 cm apart | 28.6 b | 22.8 a | 14.3 a |
| **Time of mechanical control** | | | |
| 4–6 leaves stage of sugar beet | 30.3a | 24.5 a | 13.5 ab |
| 10–12 leaves stage of sugar beet | 29.8 a | 23.6 a | 13 b |
| 14–16 leaves stage of sugar beet | 27.3 a | 21.6 a | 15 a |
| **Herbicide application** | | | |
| metamitron+(phenmedipham+desmedipham+ethofumesat) | 23 b | 13.2 b | 13 a |
| triflusulfuron+ (phenmedipham+desmedipham+ethofumesat) | 35.3 a | 33.3 a | 14.6 a |

*Means in a column followed by the same letter are not significantly different at P ≤ 0.05.*

**Weeds biomass.** Results showed that treatments have had significant effect on reduction of weed biomass. The lowest *A. retroflexus*, *C. album* and total weed biomass was in twin–row 60 cm but different planting patterns had no significant effect on *D. stramonium*. Mechanical control at 4–6 leaves stage and Metamitron plus combination of phenmedipham + desmedipham + ethofumesat were the most significantly effective treatments on weeds and total weed biomass (Table 2). Study of the interactions of treatments also showed that interaction have significantly affected weeds biomass. Mean comparison of interaction of different planting patterns and time of mechanical control indicated that the lowest biomass of *A. retroflexus* (15.6 g $m^{2\ -1}$) was achieved in single–row 50 cm × mechanical control at 4–6 leaves stage and its highest was in single–row 50 cm × mechanical control at 14–16 leaves stage (79.2 g $m^{2\ -1}$). For *C. album*, single–row 50 cm × mechanical control at 4–6 leaves stage was the best (20 g $m^{2\ -1}$) and single–row 50 cm × mechanical control at 10–12 leaves stage was the worst (101.6 g $m^{2\ -1}$) treatment. Single–row 60 cm × mechanical control at 4–6 leaves stage was the best treatment to control *D. stramonium* (8.4 g $m^{2\ -1}$). Finally, for total weed biomass, single–row 50 cm × mechanical control at 4–6 leaves stage was the best and single–row 50 cm × mechanical control at 10–20 leaves stage was the worst treatment (Table 4).

Interaction of planting pattern × herbicide was also significant and single–row 50 cm × metamitron plus combination of phenmedipham + desmedipham + ethofumesat had the most controlling effect on biomass of *A. retroflexus* and *D. stramonium* but for *C. album*, results were different and the best treatment was twin–row 60 cm × metamitron plus combination of phenmedipham + desmedipham + ethofumesat (Table 5).

Mean comparison of interaction of mechanical control × herbicide showed that the most effective treatment for controlling *A. retroflexus* and *D. stramonium* is mechanical control at 10–20 leaves stage × metamitron plus combination of phenmedipham + desmedipham + ethofumesat. For *C. album* and total weed biomass, mechanical control at 4–6 leaves stage × metamitron plus combination of phenmedipham + desmedipham + ethofumesat was the best treatment (Table 6). Mean comparison of the triple interaction of planting pattern × mechanical control × herbicide also indicated that single–row 50 cm × mechanical control at 4–6 leaves stage × metamitron plus combination of phenmedipham + desmedipham + ethofumesat has controlled all three weeds and total weed biomass the best (Table 7).

**Table 2. Mean comparison of main effects of treatments on weeds biomass (g $m^{2\ -1}$)**

| Treatments | *A. retroflexus* | *C. Album* | *D. stramonium* | total dry weight |
|---|---|---|---|---|
| **Planting pattern** | | | | |
| single row spaced 50 cm apart | 46.9 a | 66.1 a | 16.1 a | 190.9 a |
| single row spaced 60 cm apart | 48.9 a | 64.8 a | 15 a | 175.2 a |
| twin row spaced 60 cm apart | 28.4 b | 39.6 b | 18.4 a | 134 b |
| **Time of mechanical control** | | | | |
| 4-6 leaves stage of sugar beet | 27.3 c | 29.8 b | 12.7 b | 53.7 c |
| 10-12 leaves stage of sugar beet | 44.6 b | 71.6 a | 12.9 b | 82.2 a |
| 14-16 leaves stage of sugar beet | 52.2 a | 69.1 a | 18.4 a | 164.9 a |
| **Herbicide Application** | | | | |
| metamitron+(phenmedipham+desmedipham+ethofumesat) | 31.1 b | 19 b | 10.9 b | 103.3 b |
| triflusulfuron+ (phenmedipham+desmedipham+ethofumesat) | 51.7 a | 94.7 a | 18.4 a | 230.6 a |

*Means in a column followed by the same letter are not significantly different at $P \leq 0.05$.*

**Root yield and sugar content of sugar beet.** Among three treatments, effect of planting pattern was significant on root yield and sugar content but time of mechanical control and herbicide had significant effect only on root yield. Mean comparison showed no significant effect of treatments on sugar content. For root yield, different times of mechanical control and herbicides had significant effect in the way that mechanical control at 10–20 leaves stage and metamitron plus combination of phenmedipham + desmedipham + ethofumesat resulted in highest sugar beet root yield (Table 3). Results showed that triple interaction of treatment had significant effect on measured traits and the best treatment to increase root yield was single–row 60 cm × mechanical control at 10–12 leaves stage × metamitron plus combination of phenmedipham + desmedipham + ethofumesat. Interaction of planting pattern × mechanical control on sugar beet root yield was significant and highest root fresh weight was achieved in single–row 60 cm × mechanical control at 10–20 leaves stage. None of the interaction could affect sugar content significantly (figs 1, 2).

**Table 3. Mean comparison of main effects of treatments on sugar beet root yield and sugar content.**

| Treatment | Root yield ($t\ h^{-1}$) | Sugar content (%) |
|---|---|---|
| **Planting pattern** | | |
| single row spaced 50 cm apart | 15.104 a | 17.8 a |
| single row spaced 60 cm apart | 16.110 a | 18.3 a |
| twin row spaced 60 cm apart | 11.680 a | 17.9 a |
| **Time of mechanical control** | | |
| 4-6 leaves stage of sugar beet | 12.055 b | 17.9 a |
| 10-12 leaves stage of sugar beet | 17.860 a | 18.1 a |
| 14-16 leaves stage of sugar beet | 12.886 b | 18 a |
| **Herbicide application** | | |
| metamitron+(phenmedipham+desmedipham+ethofumesat) | 15.872 a | 17.9 a |
| triflusulfuron+ (phenmedipham+desmedipham+ethofumesat) | 12.660 b | 18.1 a |

*Means in a column followed by the same letter are not significantly different at $P \leq 0.05$.*

**Table 4. Interactions of planting pattern × time of mechanical control on weeds density and biomass.**

| Treatments | Density (plant $m^{2\ -1}$) | | Biomass (g $m^{2\ -1}$) | | | |
|---|---|---|---|---|---|---|
| Planting pattern × Time of mechanical control | *A. retroflexus* | *C. Album* | *A. retroflexus* | *C. Album* | *D. stramonium* | total dry weight |
| P1M1 | 20 e | 24.8 ab | 15.6 d | 20 d | 9.2 c | 34 c |
| P1M2 | 18.8 e | 20 bc | 45.6 b | 101.6 a | 19.6 b | 342.4 a |
| P1M3 | 31.2 bc | 23.2 ab | 79.2 a | 66 c | 44 b | 196 b |
| P2M1 | 32.8 bc | 18.8 bc | 46 b | 20.4 d | 8.4 c | 64.4 c |
| P2M2 | 44.4 a | 30 a | 72 a | 78.8 b | 9.2 c | 320 a |
| P2M3 | 28.8 cd | 23.2 ab | 30.8 c | 85.2 b | 10.8 c | 140.8 b |
| P3M1 | 38 ab | 29.2 a | 18.8 d | 28.8 d | 20.4 b | 62.4 c |
| P3M2 | 25.2 cde | 14.8 c | 18.9 d | 34 d | 9.6 c | 48 b |
| P3M3 | 28.de | 24 ab | 46 b | 55.6 c | 25.2 a | 157.2 b |

*Means in a column followed by the same letter are not significantly different at $P \leq 0.05$.*

**Table 5. Interactions of planting pattern × herbicide application on weeds density and biomass.**

| Treatments | Density (plant $m^{2\ -1}$) | | Biomass (g $m^{2\ -1}$) | | | |
|---|---|---|---|---|---|---|
| Planting pattern × Herbicide application | *A. retroflexus* | *C. Album* | *A. retroflexus* | *C. Album* | *D. stramonium* | total dry weight |
| P1C1 | 11.6 d | 10 c | 23.6 d | 22 c | 8 c | 32.4 d |
| P1C2 | 35.2 b | 35.6 a | 70 a | 110 a | 24 a | 250.4 b |
| P2C1 | 28 c | 15.6 b | 37.2 c | 19.6 cd | 8.8 c | 70.4 e |
| P2C2 | 42.4 a | 32.4 a | 62.4 b | 109.6 a | 10 c | 279.6 a |
| P3C1 | 28.8 c | 14 bc | 32 c | 14.8 d | 15.6 b | 26.9 d |
| P3C2 | 27.6 c | 31.6 a | 24.4 d | 64 b | 20.8 a | 40.4 c |

*Means in a column followed by the same letter are not significantly different at $P \leq 0.05$.*

**Table 6. Interactions of time of mechanical control × herbicide application on weeds density and biomass.**

| Treatment | Density (plant $m^{2\ -1}$) | Biomass (g $m^{2\ -1}$) | | | |
|---|---|---|---|---|---|
| Time of mechanical control × Herbicide application | *A. retroflexus* | *A. retroflexus* | *C. Album* | *D. stramonium* | total dry weight |
| M1C1 | 14.8 d | 28 c | 15.2 d | 15.2 b | 32 e |
| M1C2 | 34 b | 26.4 c | 44 b | 9.6 c | 75.2 d |
| M2C1 | 27.2 c | 13.2 c | 24.4 c | 7.8 c | 194.8 c |
| M2C2 | 32 bc | 65.6 a | 118.4a | 16.8 b | 369.2 a |
| M3C1 | 24.4 c | 39.6 b | 16.8 d | 8.7 c | 82.4 d |
| M3C2 | 39.6 a | 64.4 a | 121.2 a | 28 a | 264.8 b |

*Means in a column followed by the same letter are not significantly different at $P \leq 0.05$.*

**Table 7. Interactions of planting pattern × time of mechanical control × herbicide application on weeds density and biomass**

| Treatment | Density (plant m² $^{-1}$) | | Biomass (g m² $^{-1}$) | | | |
|---|---|---|---|---|---|---|
| Planting pattern × Time of mechanical control × Herbicide application | *A. retroflexus* | *C. Album* | *A. retroflexus* | *C. Album* | *D. stramonium* | total dry weight |
| P1M1C1 | 8.8 e | 8 h | 14 g | 12 h | 7.6 c | 14 h |
| P1M1C2 | 30.8 bc | 41 a | 16.8 g | 48.8 fg | 10.4 c | 54.4 gh |
| P1M2C1 | 10 e | 12.8 efgh | 79.2 g | 41.2 g | 12 c | 264.8 c |
| P1M2C2 | 28 c | 26.8 bc | 78.4 c | 162 a | 31.2 b | 420 b |
| P1M3C1 | 16 de | 8.8 gh | 44.4 ef | 12.8 h | 8 c | 115.2 ef |
| P1M3C2 | 46.8 a | 38 a | 114.4 a | 19.2 h | 30.4 b | 276.8 c |
| P2M1C1 | 26 c | 14.8defgh | 47.2 e | 19.2 h | 8 c | 22.8 h |
| P2M1C2 | 40 b | 22.8 cd | 45.2 ef | 41.2 g | 8.8 c | 106 fg |
| P2M2C1 | 46 a | 18 cdefg | 46.8 e | 19.6 h | 8.8 c | 160 e |
| P2M2C2 | 42.8 a | 42 a | 97.6 b | 138 c | 9.2 c | 480 a |
| P2M3C1 | 12.8 e | 14 defgh | 17.2 g | 20 h | 9.6 c | 29.2 h |
| P2M3C2 | 44.8 a | 32.8 ab | 44.8 ef | 150.4 b | 11.6 c | 252.8 cd |
| P3M1C1 | 44.8 a | 18.8 cdef | 22.4 g | 14.4 h | 30.4 b | 59.2 gh |
| P3M1C2 | 30.8 bc | 40 a | 17.6 g | 42.8 g | 10 c | 65.2 fgh |
| P3M2C1 | 26 c | 10 fgh | 16 g | 12.8 h | 8.8 c | 160 e |
| P3M2C2 | 24.8 cd | 20 cde | 21.2 g | 55.2 f | 10 c | 208 d |
| P3M3C1 | 16 de | 12.8 efgh | 57.6 d | 17.6 h | 8.6 c | 100 fg |
| P3M3C2 | 26.8 c | 34.8 ab | 34.4 f | 94 e | 42.4 a | 211.6d |

*Means in a column followed by the same letter are not significantly different at $P \leq 0.05$.*

*In all tables, P1: single–row 50 cm, P2: single–row 60 cm, p3: twin–row 60 cm, M1: mechanical control at 4–6 leaves stage, M2: at 10–12 leaves stage, M3: at 14–16 leaves stage, C1: metamitron plus combination of phenmedipham + desmedipham + ethofumesat, C2: triflusulfuron plus combination of phenmedipham + desmedipham + ethofumesat.*

Although treatments had significant effect on weeds control, but their effect on sugar beet measured traits was ignorable. Additionally, the low yield of sugar beet in this experiment can be related to heavy weed infestation and soil quality of the field so if the field soil quality was better to suit sugar beet, treatments could increase yield more effectively.

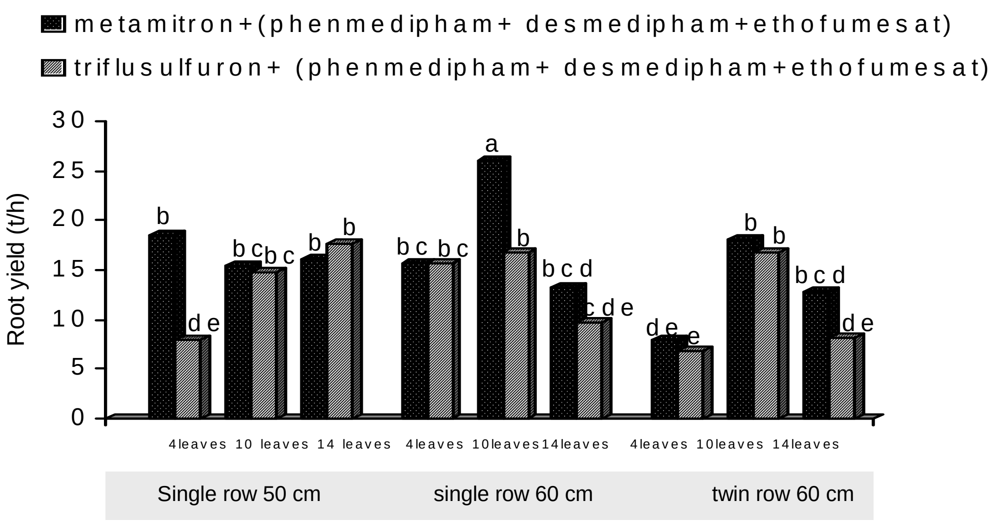


**Fig. 1. Interactions of planting pattern × time of mechanical control × herbicide application on sugar beet root yield.**

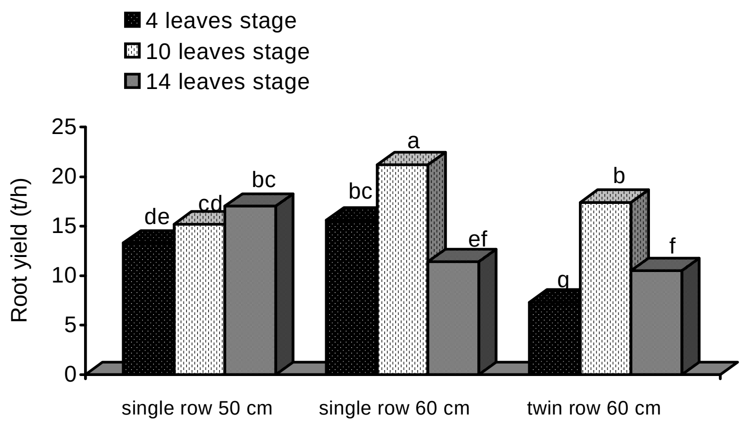


**Fig. 2. Interactions of planting pattern × time of mechanical control on sugar beet root yield.**

## DISCUSSION

As seen in results, mechanical control at 4 leaves stage of sugar best had the best effect on reduction of weed density and biomass and also on improvement of sugar beet root yield. In fact when weeds are at the early stages of growth, their roots and shoots are weak and mechanical control can eliminate the before crop yield suffer. After 4–6 leaves stage, sugar beet has a critical period of weed competition and weeds establish in field so it will be difficult to mechanically control them and on the other hand, they have damaged the crop yield. An experiment showed that hand weeding 10–12 weeks after sugar beet planting will keep the field free of weeds until the harvest time [9].

Among herbicide treatments, metamitron plus combination of phenmedipham + desmedipham + ethofumesat had better effect on weeds density and biomass and sugar beet root yield than triflusulfuron–methyl. Metamitron plus combination of phenmedipham + desmedipham + ethofumesat control some weeds like *A. retroflexus* and *C. album* usually well but some weeds can avoid the damage of triflusulfuron–methyl. In an experiment researchers understood that the best time for application of metamitron is between sugar beet planting and 2 leaves stage so the herbicide can suppress *A. retroflexus* and *C. album* [11].

For cultural weed management, a square like planting pattern (twin–row with 60 cm width and plants spacing of 33.3 cm) was tested. In this type of planting pattern, crop will cover the soil better and lower space will remain for weeds so the crop will dominate weeds. In this experiment, twin–row 60 cm showed considerable control on weeds biomass. An experiment tested the effect of planting pattern on weed management in a sugar beet field and resulted that rectangular planting patter will help weeds to grow better and occupy more land and it will reduce crop growth and yield [12].

## CONCLUSION

Overall results of this experiment indicate that the best time of mechanical weed control is at sugar beet 4–6 leaves stage and the best herbicide is metamitron plus combination of phenmedipham + desmedipham + ethofumesat that showed the highest control on weeds in all cases. It is not possible to select one of the planting patterns as the best for weeds density control but for weeds biomass control twin–row 60 cm is the most effective planting pattern.

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