Agronomic Evaluation of Mechanical and Chemical Weed Management for Reducing Use of Herbicides in Single vs. Twin-Row Sugar Beet

Meisam Zargar, Elena Pakina, and Petr Dokukin
Department of Plant Protection, People's Friendship University, Moscow, Russia
Email: meisam.za_ir84@yahoo.com, e-pakina@yandex.ru

***Abstract*—In order to evaluate the effects of chemical and non-chemical weed management in in sugar beet, an experiment was carried out at a research farm in Karaj. The experimental factors were arranged in split–split plot based on a complete randomized block design with four replications. Planting pattern was allotted as main-plot (single row planting with 50cm row width, single row planting with 60cm row width and twin row planting with 60cm row width), time of mechanical control as sub–plot (mechanical weed control at 4 leaves stage, 10 leaves stage and 14 leaves stage of sugar beet), and herbicides as sub–sub plot (metamitron plus combination of phenmedipham + desmedipham + ethofumesat and triflusulfuron metil plus combination of phenmedipham + desmedipham + ethofumesat). The results showed that planting pattern had proper effect on weeds biomass that best results were obtained in twin row planting 60cm. Also, mechanical control at 4 leaves stage of sugar beet had the best effect on weeds density and biomass. metamitron plus combination of phenmedipham + desmedipham + ethofumesat had also the best effect on weeds density and biomass.**

***Index Terms*—weed, herbicide, planting pattern, mechanical control**

I. Introduction

Mechanical and cultural methods are as the most important of non-chemical ways for weed management that are inexpensive methods for reducing weeds competition [1]-[4]. 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 [5]. Hoeing is the most common mechanical weed control method in organic sugar beet (Beta vulgaris L.) production. Hoeing machines are usually used to control the weeds between the rows (inter row weeding), whereas manual hoeing is used to remove weeds between sugar beet plants in the row (intra-row weeding). Manual weed hoeing in organic sugar beet production often accounts for 150 man-hours/ha [6]. To evaluate effect of planting pattern on the weed management, an experiment was conducted by Fischer & Miles [7] and determined that when the planting pattern is in rectangular form, the percentage of land occupied by weeds is more compared to square planting pattern. 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 [8]. 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 [9]. Brecke & Stephanson [4] also found that twin–row planting pattern of peanut is better than single–row. 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 [10]. Johnson *et al.* [11] found that total weed densities were less when peanut rows were spaced 30cm apart compared to rows spaced 91cm apart. Similar results were obtained by Buchanan & Hauser [12]. The aim 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.

II. Materials & Methods

Sugar beet (var: Rasul) was planted at 100000 plants ha^{-1} in both single and twin row system. Consequently, sugar beat was planted with 20, 16.6 and 33.3cm in single row 50cm, single row 60cm and twin row 60cm width respectively.

Weeds density and biomass were studied 30 days after herbicides application. To do this, a 50×50cm quadrate was installed in each plot and number of weeds was counted before spraying and 30 days after spraying. For measure the biomass of weeds, 30 days after spraying weeds in quadrates were harvested and oven dried at 75 ℃.

ANOVA was conducted on all data using of SAS [13] and means separated using Duncan's multiple range test at 0.05 probability levels.

III. Results & Discussion

A. Response of Weeds to Treatments

Result showed that different types of planting patterns have affected density of *A. retroflexus* significantly in the

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way that lowest density of this weed 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, and triflusulfuron–methyl plus combination of phenmedipham + desmedipham + ethofumesat controlled them the worst (Table I). Metamitron plus combination of phenmedipham + desmedipham + ethofumesat had better effect on weeds than 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* [14].

Interactions of planting pattern with mechanical control and planting pattern with herbicide and also planting pattern, time of mechanical control and herbicide was significant on density of A. *retroflexus* and C. *album*, but interaction of time of mechanical control and herbicide was significant only on density of A. *retroflexus*. The lowest biomass of A. *retroflexus*, C. *album* was in twin–row 60cm but different planting patterns had no significant effect on H. trionum. Mechanical control at 4 leaves stage and Metamitron plus combination of phenmedipham + desmedipham + ethofumesat were the most significantly effective treatments on weeds (Table II). Mean comparison of interaction of planting pattern and mechanical control showed that single–row 50cm and mechanical control at 10 leaves stage of sugar beet was the best for controlling A. *retroflexus* and twin–row 60cm and mechanical control at 10 leaves stage was the best treatment for controlling C. *album* (Table III). Also, interaction of single–row 50cm and metamitron plus combination of phenmedipham + desmedipham + ethofumesat has had the most controlling effect on A. *retroflexus* and C. *album* (Table IV). Moreover, evaluate of the interaction of mechanical control and herbicide shows that the lowest density of A. *retroflexus* was obtained in mechanical control at 4 leaves stage and metamitron (Table V). Generally, single–row 50cm, mechanical control at 4 leaves stage and metamitron plus combination of phenmedipham + desmedipham + ethofumesat has been the most effective treatment on weeds (Table VI).

Mechanical control at 4 leaves stage of sugar best had the best effect on reduction of weed biomass. 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. An experiment showed that hand weeding 10–12 weeks after sugar beet planting will keep the field free of weeds until the harvest time [5].

Mean comparison of interaction of different planting patterns and time of mechanical control indicated that the lowest biomass of *A. retroflexus* was obtained in single–row 50cm and mechanical control at 4 leaves stage. For *C. album*, single–row 50cm and mechanical control at 4 leaves stage was the treatment. Single–row 60cm and mechanical control at 4 leaves stage was the best treatment to control *H. trionum* (Table III).

Interaction of planting pattern and herbicide was also significant and single–row 50cm and metamitron had the most controlling effect on biomass of *A. retroflexus* and *H. trionum* but for *C. album*, results were different and the best treatment was twin–row 60cm and metamitron (Table IV). The most effective treatment for controlling *A. retroflexus* and *H. trionum* was mechanical control at 10 leaves stage and metamitron plus combination of phenmedipham + desmedipham + ethofumesat. For *C. album*, mechanical control at 4 leaves stage and metamitron was the best treatment (Table V). Mean comparison of the triple interaction of treatments also indicated that single–row 50cm, mechanical control at 4 leaves stage and metamitron plus combination of phenmedipham + desmedipham + ethofumesat has controlled all three weeds the best (Table VI).

TABLE I. EFFECTS OF TREATMENTS ON WEEDS DENSITY (PLANT M^{2-1})

Treatments	*H. Trionum*	*C. Album*	*A. retroflexus*
Planting pattern			
single row spaced 50cm apart	13.1 a	22.8 a	23.5 c
single row spaced 60cm apart	13.3 a	24.1 a	35.3 a
twin row spaced 60cm apart	14 a	22.8 a	28.6 b
Mechanical control			
4 leaves stage of sugar beet	13.8 ab	24.5 a	30.3a
10 leaves stage of sugar beet	12.9 b	23.6 a	29.8 a
14 leaves stage of sugar beet	14.8 a	21.6 a	27.3 a
Herbicide application			
Metamitron	13.3 a	13.2 b	23 b
Triflusulfuron	12.9 a	33.3 a	35.3 a

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

TABLE II. EFFECTS OF TREATMENTS ON WEEDS BIOMASS (G M^{2-1})

Treatments	*H. trionum*	*C. Album*	*A. retroflexus*
Planting pattern			
single row spaced 50cm apart	15.8 a	66.1 a	46.9 a
single row spaced 60cm apart	15.2 a	64.8 a	48.9 a
twin row spaced 60cm apart	16.5 a	39.6 b	28.4 b
Mechanical control			
4 leaves stage of sugar beet	12.5 b	29.8 b	27.3 c
10 leaves stage of sugar beet	13 b	71.6 a	44.6 b
14 leaves stage of sugar beet	17.9 a	69.1 a	52.2 a
Herbicide application			
metamitron	11.1 b	19 b	31.1 b
triflusulfuron	19 a	94.7 a	51.7 a

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

TABLE III. INTERACTIONS OF PLANTING PATTERN AND MECHANICAL CONTROL ON WEEDS

Treatments	Density (plant m^{2-1})		Biomass (g m^{2-1})		
Planting pattern × mechanical control	*A. retroflexus*	*C. Album*	*H. Trionum*	*C. Album*	*A. retroflexus*
P1M1	20 e	24.8 ab	8.9 c	20 d	15.6 d
P1M2	18.8 e	20 bc	20 b	101.6 a	45.6 b
P1M3	31.2 bc	23.2 ab	44 b	66 c	79.2 a
P2M1	32.8 bc	18.8 bc	8 c	20.4 d	46 b
P2M2	44.4 a	30 a	9.1 c	78.8 b	72 a
P2M3	28.8 cd	23.2 ab	10.2 c	85.2 b	30.8 c
P3M1	38 ab	29.2 a	20.2 b	28.8 d	18.8 d
P3M2	25.2 cde	14.8 c	9.8 c	34 d	18.9 d
P3M3	28.de	24 ab	25.5 a	55.6 c	46 b

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

TABLE IV. INTERACTIONS OF PLANTING PATTERN AND HERBICIDE ON WEEDS

Treatments	Density (plant m^{2-1})		Biomass (g m^{2-1})		
Planting pattern × Herbicide	*A. retroflexus*	*C. Album*	*H. Trionum*	*C. Album*	*A. retroflexus*
P1C1	11.6 d	10 c	9 c	22 c	23.6 d
P1C2	35.2 b	35.6 a	24.1 a	110 a	70 a
P2C1	28 c	15.6 b	9.3 c	19.6 cd	37.2 c
P2C2	42.4 a	32.4 a	10.1 c	109.6 a	62.4 b
P3C1	28.8 c	14 bc	15.6 b	14.8 d	32 c
P3C2	27.6 c	31.6 a	21 a	64 b	24.4 d

Means in columns followed by the same letter are not significantly different at $P \leq 0.05$

TABLE V. INTERACTIONS OF MECHANICAL CONTROL AND HERBICIDE ON WEEDS

Treatment	Density (plant m^{2-1})	Biomass (g m^{2-1})		
Mechanical control × Herbicide	*A. retroflexus*	*H. Trionum*	*C. Album*	*A. retroflexus*
M1C1	14.8 d	14.9 b	15.2 d	28 c
M1C2	34 b	9.8 c	44 b	26.4 c
M2C1	27.2 c	8.1 c	24.4 c	13.2 c
M2C2	32 bc	15.9 b	118.4a	65.6 a
M3C1	24.4 c	9 c	16.8 d	39.6 b
M3C2	39.6 a	27.8 a	121.2 a	64.4 a

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

TABLE VI. INTERACTIONS OF PLANTING PATTERN, MECHANICAL CONTROL AND HERBICIDE ON WEEDS

Treatment	Density (plant m $^{2-1}$)		Biomass (g m $^{2-1}$)		
Planting pattern × Mechanical control × Herbicide	*A. retroflexus*	*C. Album*	*H. Trionum*	*C. Album*	*A. retroflexus*
P1M1C1	8.8 e	8 h	7.1 c	12 h	14 g
P1M1C2	30.8 bc	41 a	10.7 c	48.8 fg	16.8 g
P1M2C1	10 e	12.8 efgh	11.8 c	41.2 g	79.2 g
P1M2C2	28 c	26.8 bc	31.1 b	162 a	78.4 c
P1M3C1	16 de	8.8 gh	8.1 c	12.8 h	44.4 ef
P1M3C2	46.8 a	38 a	29 b	19.2 h	114.4 a
P2M1C1	26 c	14.8defgh	8.1 c	19.2 h	47.2 e
P2M1C2	40 b	22.8 cd	8.9 c	41.2 g	45.2 ef
P2M2C1	46 a	18 cdefg	8.9 c	19.6 h	46.8 e
P2M2C2	42.8 a	42 a	9.2 c	138 c	97.6 b
P2M3C1	12.8 e	14 defgh	9.6 c	20 h	17.2 g
P2M3C2	44.8 a	32.8 ab	10.9 c	150.4 b	44.8 ef
P3M1C1	44.8 a	18.8 cdef	29 b	14.4 h	22.4 g
P3M1C2	30.8 bc	40 a	10.1 c	42.8 g	17.6 g
P3M2C1	26 c	10 fgh	8.8 c	12.8 h	16 g
P3M2C2	24.8 cd	20 cde	9.9 c	55.2 f	21.2 g
P3M3C1	16 de	12.8 efgh	8.6 c	17.6 h	57.6 d
P3M3C2	26.8 c	34.8 ab	40.2 a	94 e	34.4 f

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

TABLE VII. EFFECTS OF TREATMENTS ON 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
Mechanical control		
4 leaves stage of sugar beet	12.055 b	17.9 a
10 leaves stage of sugar beet	17.860 a	18.1 a
14 leaves stage of sugar beet	12.886 b	18 a
Herbicide application		
metamitron	15.872 a	17.9 a
triflusulfuron	12.660 b	18.1 a

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

For cultural weed management, a square like planting pattern (twin–row with 60cm width and plants spacing of 33.3cm) 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 60cm 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 pattern will help weeds to grow better and occupy more land and it will reduce crop growth and yield [Table VII]. Mean comparison was only conducted for the weeds which were significantly affected by the treatments.

B. *Root Yield and Sugar Content*

Effect of planting pattern was significant on sugar content and root yield but 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 leaves stage and metamitron resulted in highest sugar beet root yield (Table VII). Triple interaction of treatment had significant effect on measured traits of sugar beet and the best treatment to increase root yield was single–row

60cm, mechanical control at 10 leaves stage and metamitron plus combination of phenmedipham + desmedipham + ethofumesat. Interaction of planting pattern and mechanical control on sugar beet root yield was significant and highest root fresh weight was obtained in single–row 60 cm and mechanical control at 10 leaves stage. None of the interaction could affect significantly (Table VIII, IX).

Also, treatments had significant effect on weeds control, but their effect on sugar beet measured traits was ignorable.

TABLE VIII. INTERACTIONS OF PLANTING PATTERN, MECHANICAL CONTROL AND HERBICIDE ON ROOT YIELD

Planting pattern × Mechanical control × Herbicide	Root yield (t h $^{-1}$)
P1M1C1	18.5b
P1M1C2	8de
P1M2C1	15.4bc
P1M2C2	14.8bc
P1M3C1	16.1b
P1M3C2	17.6b
P2M1C1	15.5bc
P2M1C2	15.6bc
P2M2C1	25.4a
P2M2C2	16.7b
P2M3C1	13bcd
P2M3C2	9.5cde
P3M1C1	7.9de
P3M1C2	6.6e
P3M2C1	18b
P3M2C2	16.6b
P3M3C1	12.6bcde
P3M3C2	8.1de

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

TABLE IX. INTERACTIONS OF PLANTING PATTERN AND MECHANICAL CONTROL ON ROOT YIELD

Treatments Planting pattern × Mechanical control	Root yield (t h $^{-1}$)
P1M1	13.2de
P1M2	15.1cd
P1M3	16.9bc
P2M1	15.7bc
P2M2	21.1a
P2M3	11.3ef
P3M1	7.2g
P3M2	17.3b
P3M3	10.4f

Means in columns 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 leaves stage, M2: at 10 leaves stage, M3: at 14 leaves stage, C1: metamitron plus combination of phenmedipham +desmedipham+ethofumesat, C2: triflusulfuron plus combination of phenmedipham+desmedipham+ethofumesat

IV. CONCLUSION

In conclusion, the best herbicide was metamitron plus combination of phenmedipham + desmedipham + ethofumesat that showed the highest control on weeds in most cases and the best time of mechanical weed control was at sugar beet 4 leaves stage. 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 60cm was the most effective planting pattern.

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Meisam Zargar was born in Karaj City, Iran in 1984. He got Ph.D. in weed science program at the People's Friendship University of Russia under the supervision of Dr. Peter M Polityko at the Moscow Scientific Research Institute of Agriculture. Before joining Dr. Peter M Polityko Group, he worked as a master student under the supervision of Dr. Eskandar Zand in the Department of Plant Protection of Iran at optimizing the integrated weed management in sugar beet field. Bachelor degree was in plant production field in Islamic Azad University of Iran.

He passed military service in Iranian Army in 2007. After graduating Doctorate degree he worked as a lecturer in People's Friendship University of Russia till now. Three books published by People's Friendship University of Russia publisher, with tiles of Weed management strategies, Pest control principals and Statistical designs in agricultural researches.

Dr. Zargar is member in below listed organizations and groups:
Biosafety Society of Iran (since 2009).
Weed Science Society of Iran (since 2009).
Iranian Agricultural and Natural Resources Engineering Organization (since 2007).
Asia-Pacific Chemical, Biological& Environmental Engineering Society (APCBEES) (since 2013).
Iranian Association for Energy Economics.