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Effect of different single herbicide doses on sugar beet yield, quality and associated weeds

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Abstract

Background: The objective of this work is to identify the most proper herbicidal treatment on sugar beet to compare different single weed control herbicide doses on sugar beet traits and associated weeds as well as yield and quality under sandy soil conditions. Therefore, two field experiments were conducted during the winter seasons of 2017/2018 and 2018/2019 at the Experimental Farm of the National Research Centre, El-Beheira Governorate. Tigro at 1.0 and 0.750 l fed^{-1}, Betasana-Trio at 0.675 and at 0.9 l fed^{-1}, Select Super at 0.5 and 0.375 l fed^{-1} and Betanal MaxxPro at 0.5 l fed^{-1} besides the unweeded and hand weeded twice were used.

Results: The results showed that the herbicides Betasana-Trio at 0.9 l fed^{-1}, Tigro at 1.0 l fed^{-1} and Betasana-Trio at 0.675 l fed^{-1} when sprayed twice could effectively and/or completely eliminate the broadleaved weeds associated with sugar beet plants. Moreover, the results indicated and confirmed that Tigro and Betasana-Trio herbicides are effective in controlling broadleaved weeds. Similar tendency was recorded for the narrow-leaved weeds, where Select Super or Betanal MaxxPro at 0.5 l fed^{-1} as well as Select Super at 0.375 l fed^{-1} could completely eliminate or minimize the narrow-leaved weeds associated with sugar beet plants. The greatest significant root length, root diameters and root yield plant^{-1} were recorded when hand weeding twice followed by Betanal MaxxPro at 0.5 l fed^{-1} without significant differences. Gross sugar % ranged between 12.08 and 15 .7% and extractable sugar % ranged between 8.97 and 13.8% for Betasana-Trio at 0.09 l fed^{-1} and Betanal MaxxPro at 0.5 l fed^{-1}.

Conclusion: Betanal MaxxPro gave the highest values of root and biological yield ton fed^{-1}. Betanal MaxxPro followed by hand weeding treatment twice resulted in the greatest sugar yield fed^{-1}. The highest sugar yield resulted from the herbicidal treatment with Betanal MaxxPro or Tigro at 1.0 l fed^{-1}, which gave the greatest gross and extractable sugar yield fed^{-1} and exceeded the hand weeding treatment by 10.4 and 7.8%.

Keywords: Sugar beet, Weeds, Herbicide, Yield, quality

Background

It is well known that weeds interfere with crop plants causing serious impacts either in the competition for light, water, nutrients and space or in the allelopathy. Weed suppression by shading only begins after the canopy of sugar beet leaves grown over the rows and early coverage of field. Faster growth of weeds is disadvantageous for light and hence photosynthesis needed for sugar beet plants. Through this light deprivation, less energy is available to crop plant for metabolic production and hence growth, yield and quality of sugar beet will be reduced. In addition, weeds with branched, vigorous root systems inhibit the development of sugar beet plants through severe nutrition deprivation. Up to 100% of the crop yield may be lost because of weed competition if weed control is poor or not performed

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at all (Schweizer and Dexter 1987). Special attention on weed control has to be paid during the critical period at an early stage of sugar beet development (Bezhin et al. 2015), a period of the first 60 days after emergence when sugar beet does not tolerate competitive interactions with weeds without losing yield (Kobusch 2003; Petersen 2008; Jalali and Salehi 2013).

Competition between sugar beet and annual weeds could be responsible for sugar yield reductions of 26–100% (Cioni and Maines 2011). Weed control in crops is mainly based on the use of herbicides because they are efficient and easily applied (Lodovichi et al. 2013). The use of herbicides may reduce yield losses, as herbicides can reduce the weed infestation (Mehmeti 2004). Majidi et al. (2011) showed that using a combination of broad-leaved herbicides-controlled weeds and root yields to be increased. Herbicidal treatment can result in low crop interference with weeds (Jursík et al. 2008). Majidi et al. (2017) reported that several herbicides are registered for selective weed control in sugar beet; however, no single chemical herbicide can control all weeds in beet fields.

Hand hoeing is still the conventional weeds control practice in sugar beet fields in Egypt. In the last decades, the hand labor is becoming scarce and their wages have been increased. However, the manual weeding could not be perfectly provided. This in turn presents to view the needs for another reasonable alternative tool. Herbicide treatment alone surpassed some hand hoeing treatments. In this respect, Abo El-Hassan (2010) found that root length, root diameter, root weight, top fresh weight, top yield, root yield and sugar yield of sugar beet were significantly affected by weed control treatments. Also, Tagour et al. (2012) found that hand hoeing twice with mulching gave the highest values of tops, roots, biological and sugar yields. May (2003) reported that sugar beet is a poor competitor with weeds in arable fields because it is slow growing early in the season and has a low canopy. Sugar beet is not competitive with emerging weeds until it has at least eight true leaves. The total potential losses from weeds are estimated between 50 and 100% of the potential crop yield (May 2001).

Therefore, the objective of this work is to identify the most proper herbicidal treatment on sugar beet yield and quality under sandy soil conditions.

Methods

During the winter seasons of 2017/2018 and 2018/2019, two field experiments were conducted at the Experimental Farm of the National Research Centre (latitude of 30.87° N and longitude of 31.17° E and mean altitude 21 m above sea level), El-Beheira Governorate, to evaluate different herbicidal treatments on sugar beet yield characters and associated weeds. The experimental soil was sandy, and the mechanical and chemical analysis of the soil is presented in Table 1.

Sugar beet cultivar Baraka was sown in hills 25 cm apart at a rate of 2 kg fed^{-1} by hand in rows in 21 and 29 November in 2017/2018 and 2018/2019 seasons, respectively. The experimental design was a completely randomized block design in four replicates. The common, trade and chemical names of used herbicides as well as mode of action, rate and time of application are listed in Table 2.

Single weed control herbicide doses were used, and the experiment included the following treatments:

1) Tigro 1.0 l fed^{-1}.
2) Tigro 0.750 l fed^{-1}.
3) Betasana-Trio 0.9 l fed^{-1}.
4) Betasana-Trio 0.675 l fed^{-1}.
5) Select Super 0.5 l fed^{-1}.
6) Select Super 0.375 l fed^{-1}.
7) Betanal MaxxPro 0.5 l fed^{-1}.
8) Hand weeding twice.
9) Unweeded control.

Herbicides were sprayed by Knapsack sprayer (at 200 L fed^{-1}). The normal cultural practices for growing sugar beet in sandy soil were applied as recommended, except for weed control measures.

Studied characters

Weed flora

A sample of weeds in 1 m2 was taken from each experimental unit to determine the number and fresh weights of broadleaved, narrow-leaved and total number of weeds. Thereafter, the weed samples were dried and dry weights were recorded.

The eradication % of weeds was calculated as follows:

Table 1 Mechanical and chemical analysis of experimental soil

Sand %	Silt %	Clay %	pH	Organic matter, %	$CaCo_3$%	E.C. ds/m	Soluble N, ppm	Available P, ppm	Exchangeable K, ppm
91.2	3.7	5.1	7.3	0.3	1.4	0.3	8.1	3.2	20

Table 2 Common, trade and chemical names of the herbicides used as well as mode of action, rate and time of application

Common name	Trade name	Chemical name	Mode of action	Rate of application	Time of application
Desmedipham	Betanal MaxxPro	Desmedipham—47 g /l Ethofumesate—75 g/l Lenacil—27 g/l Phenmedipham—60 g /l	Classical photosynthesis inhibitors	500 cm fed^{-1}	At the age of 2–3 real leaves at sugar beet
Ethofumesate	Betasana-Trio	Ethofumesate—115 g/l (11.5% w/w) Phenmedipham—75 g/l (7.65% w/w) Desmedipham—15 g/l (1.55% w/w)	Classical photosynthesis inhibitors	900 cm + 900 cm fed^{-1}	At the age of two real leaves on sugar beet and repeat treatment after 8 days
Phenmedipham	Tigro 27.4/EC	- 91 g/l Desmedipham—71 g/l Ethofumesate—112 g/l	Classical photosynthesis inhibitors	1.0 l fed^{-1}	At the age of two real leaves on sugar beet
Clethodim	Select Super	(±)-2-[(E)-1-[(E)-3-chloroallyloxyimino]propyl]-5-[2-(ethylthio)propyl]-3-hydroxycyclohex-2-enone	Lipid biosynthesis inhibitors	500 cm fed^{-1}	At the age of 2–4 real leaves of weeds

$$\text{Eradication \%}\left(\text{fresh weight m}^{-2}\right) = \left(\text{fresh weight of weeds the unweeded} - \text{fresh weight of weeds treatment}\right) / \text{fresh weight of weeds the unweeded} \times 100$$

$$\text{Eradication \%}\left(\text{dry weight m}^{-2}\right) = \left(\text{dry weight of weeds the unweeded} - \text{dry weight of weeds treatment}\right) / \text{dry weight of weeds the unweeded} \times 100$$

$$\text{Eradication \%}\left(\text{total No. of weeds m}^{-2}\right) = (\text{No. of weeds the unweeded} - \text{No. of weeds of the unweededtreatment}) / \text{No. of weeds the unweeded} \times 100.$$

- Plant samples were taken from three replicates, and ten plants were taken from each experimental unit to estimate root characters: root length (cm), root diameter (cm), root weight (g) and top weight per plant (g).

- Yield per feddan: The number of plants in the experimental unit area was counted, top and roots weights of 3 × 3.5 m were determined, and then, total yield was calculated.

- Total chlorophyll content of sugar beet leaves was determined in both seasons as SPAD value was determined at 90 days by a chlorophyll meter (SPAD-502, Minolta Camera Co., Osaka, Japan, Minolta Co., 1989).

- Chemical composition of the roots: A sample of 5 kg of selected treatments was taken from the roots for analysis done by the sugar factory in El-Nubaria to determine chemical composition of the roots in both seasons. The determinations included polarity (gross sugar %), Qz % (juice purity %), Na, K and α-amino-N. Sugar yield per feddan was calculated by multiplying gross sugar % by root yield fed^{-1}.

Statistical analysis

The analysis of variance was carried out using MSTAT-C Computer Software (MSTAT-C, 1988) after testing the homogeneity of the error by Bartlett's test; combined analysis for both seasons was done. Means of the different treatments were compared using the least significant difference (LSD) at 5% level.

Results

Effect of weed control treatments on weed traits

The dominant weed species in the experiment included common sweet clover (*Melilotus indica* L.), wild beet (*Beta vulgaris* L.), Greater Ammi (*Ammi majus* L.) and London rocket (*Sisymbrium irio* L.) as broadleaved weeds and wild oat (*Avena fatua* L.) as well as ryegrass (*Lolium temulentum* L.) as narrow-leaved weeds.

Data in Table 3 show that weed control treatments differed significantly in their effect on fresh and dry weight of broadleaved, narrow-leaved and total weeds as well as number of broadleaved, narrow-leaved and total weeds m^{-2} after 90 days from sowing. The data showed that the herbicides Betasana-Trio at 0.9 l fed^{-1}, Tigro at 1.0 l fed^{-1} and Betasana-Trio at 0.675 l fed^{-1} could effectively or reasonably eliminate the broadleaved weeds associated

Table 3 Effect of weed control treatments on weed traits (combined data of 2017/2018 and 2018/2019)

Treatment	Fresh weight weeds (m2)			Eradication%	Dry weight weeds (m2)			Eradication%	Number of weeds (m2)			
	Broad	Narrow	Total fresh		Broad	Narrow	Total		Broad	Narrow	Total	Eradication%
Tigro 1.0 l fed^{-1}	2.0	110.2	111.2	83.6	0.5	25.1	25.6	80.0	0.4	29.0	29.4	85.7
Tigro 0.75 l fed^{-1}	4.2	160.3	164.5	75.7	1.5	36.9	38.4	69.9	3.0	35.2	38.2	81.5
Betasana-Trio 0.9 l fed^{-1} (twice)	1.1	117.0	118.1	82.6	0.2	26.4	26.6	79.2	0.2	29.1	29.3	85.8
Betasana-Trio 0.675 l fed^{-1} (twice)	4.0	139.7	143.7	78.8	0.7	30.5	31.2	75.6	2.1	33.0	35.1	83.0
Select Super 0.5 l fed^{-1}	432.9	0.1	433.0	36.0	72.6	0.1	72.7	43.1	146.5	0.1	146.6	28.8
Select Super 0.375 l fed^{-1}	450.0	3.6	453.6	33.0	75.6	0.8	76.4	40.2	154.6	0.9	155.4	24.6
Betanal MaxxPro 0.5 l fed^{-1}	30.0	0.7	30.1	95.6	5.3	0.1	5.4	95.8	12.0	0.3	12.3	94.0
Hand hoeing twice	35.0	27.0	52.0	92.3	7.1	5.2	12.3	90.4	13.0	9.0	22.0	89.0
Unweeded control	462.3	214.6	676.9	-	74.4	53.3	127.7	-	152.0	54.0	206.0	-
LSD at 0.05	14.6	7.10	15.5	-	4.8	1.0	12.2	-	7.7	1.7	4.6	-

with sugar beet plants so the number or fresh and dry weights was minimized when Betasana-Trio at 0.9 l fed^{-1} was applied. Similar tendency was recorded for the narrow-leaved weeds, where Select Super 0.5 l fed^{-1} or Betanal MaxxPro at 0.5 l fed^{-1} as well as Select Super at 0.375 l fed^{-1} could completely eliminate or minimize the narrow-leaved weeds. Data in the same table show that Betanal MaxxPro treatment recorded the highest eradication percent of the total fresh and dry weights as well as number of weeds m^{-2} followed by that of hand hoeing treatment, Betasana-Trio at 0.9 l fed^{-1} and Tigro at 1.0 l fed^{-1}, respectively.

Effect of weed control treatments on sugar beet crop characteristics

Chlorophyll content

The chlorophyll content data in Table 4 expressed as SPAD reading indicate that there was no clear tendency of the tested herbicides in their effect on chlorophyll content of sugar beet leaves. However, Tigro and Betasana-Trio herbicides at their high doses of application (1.0 and 0.9 l fed^{-1}, respectively) recorded the greatest chlorophyll content compared with the other weed control treatments (Table 4), whereas the lowest chlorophyll content was recorded by the unweeded control. There was insignificant difference among the other herbicidal treatments and hand hoeing twice.

Yield characteristics

Data in Table 4 show significant differences among weed control treatments in their effect on sugar beet root length and diameter. The highest root length and diameter were recorded when hand hoeing twice and Betanal MaxxPro were applied, respectively. The difference between Betasana-Trio treatment at 0.675 l fed^{-1} and hand weeding twice in root length and diameter was insignificant. The differences among other treatments were significant in these criteria.

The statistical analysis of the data in Table 4 revealed significant differences among weed control treatments in their effect on sugar beet yield characters. Significant differences in root and shoot yields plant^{-1} were detected. The greatest significant root yield plant^{-1} was recorded when Betanal MaxxPro and hand hoeing twice were applied, respectively. The differences among other weed control treatments were significant. The highest shoot yield plant^{-1} was obtained when Tigro at 1.0 l fed^{-1} and Select Super at 0.5 l fed^{-1} were sprayed, while the lowest fresh weight plant^{-1} was recorded when unweeded treatment was applied.

The maximum shoot yield fed^{-1} was found when the Tigro at 1.0 l fed^{-1} was applied followed by Betanal MaxxPro treatment, Select Super at 0.5 l fed^{-1} and hand hoeing twice; however, the differences among other treatments were insignificant in their effect on shoot yield fed^{-1} (Table 4). Concerning the effect of weeding practices on sugar beet root yield t fed^{-1}, all weeded plots produced greater root yields than the weedy check one. Applying Betanal MaxxPro, hand hoeing twice, Tigro at

Table 4 Effect of different herbicidal treatments on sugar beet crop characteristics (combined data of 2017/2018 and 2018/2019)

Treatment	SAPD value	Root length (cm)	Root diameter (cm)	Root yield plant^{-1} (g)	Shoot yield plant^{-1} (g)	Root yield fed^{-1} (t)	Shoot yield fed^{-1} (t)	Biological yield fed^{-1} (t)
Tigro 1.0 l fed^{-1}	47.4	28.2	7.6	391.4	195.8	27.0	13.9	40.9
Tigro 0.75 l fed^{-1}	44.2	26.8	7.6	348.8	183.8	24.3	10.2	34.5
Betasana-Trio 0.9 l fed^{-1} (twice)	47.1	25.8	7.0	384.4	178.2	25.3	9.79	35.09
Betasana-Trio 0.675 l fed^{-1} (twice)	44.4	26.3	7.2	282.9	159.8	21.25	8.71	29.96
Select Super 0.5 l fed^{-1}	41.3	26.3	7.2	282.9	189.8	21.25	13.2	34.45
Select Super 0.375 l fed^{-1}	42.8	25.8	6.6	317.6	178.9	19.1	9.79	28.89
Betanal MaxxPro 0.5 l fed^{-1}	46.8	31.8	8.6	465.0	170.6	33.9	13.6	47.5
Hand hoeing twice	46.4	33.0	8.7	413.1	185.4	31.9	12.3	44.2
Unweeded control	35.9	25.3	6.8	310.1	137.0	18.9	8.6	27.5
LSD at 0.05	4.2	2.84	0.83	9.57	12.23	2.27	1.56	3.90

Table 5 Effect of different weed control treatments on sugar beet quality

Weed control treatment	Gross sugar %	Loss %*	Juice purity % (Qz %)	K %	Na %	α-amino-N %	Extractable %	Sugar yield fed^{-1} (t)	Extractable sugar yield fed^{-1} (t)	Extractable sugar yield %*
Tigro 1.0 l fed^{-1}	15.7	19.98	80.02	4.16	3.03	4.05	12.56	4.315	3.651	112.03
Betasana-Trio 0.9 l fed^{-1} (twice)	12.08	25.72	74.28	3.65	3.26	4.76	8.97	3.368	2.886	88.53
Select Super 0.5 l fed^{-1}	14.64	20.23	79.77	3.57	3.08	4.20	11.68	2.940	2.733	72.77
Betanal MaxxPro 0.5 l fed^{-1}	15.58	16.17	83.83	3.19	2.41	3.29	13.06	3.865	3.590	110.14
Hand weeding twice	15.06	21.47	78.53	4.64	3.00	3.40	11.83	3.755	3.259	100

* Relative to hand weeding twice

1.0 l fed^{-1} and Betasana-Trio 0.9 l fed^{-1} produced high values of root yield t fed^{-1}. These treatments significantly increased root yield t fed^{-1} over the unweeded check by 79.4, 68.8, 42.9 and 33.9%, respectively (Table 4); however, the differences among Betanal MaxxPro and hand hoeing twice were insignificant in their effect on shoot yield fed^{-1}. In this connection, the maximum significant increase in biological yield t fed^{-1} was obtained by Betanal MaxxPro (72.7%) followed by hand hoeing twice (60.6%), Tigro at 1.0 l fed^{-1} (48.7%) and Betasana-Trio 0.9 l fed^{-1} (27.6%) in comparison with unweeded treatment. Insignificant differences were noticed between Betanal MaxxPro and hand hoeing twice. The obtained results clearly indicated that the application of Betanal MaxxPro, hand hoeing twice, Tigro at 1.0 l fed^{-1} (48.7%) and Betasana-Trio 0.9 l $fed^{-1}$was the best treatment in weed elimination and increasing root yield fed^{-1}.

Sugar beet root quality.

Data in Table 5 and Fig. 1 show that weed control treatments exhibited clear differences in sugar beet quality parameters, which affected sugar extraction. Gross sugar % ranged between 12.08 and 15.7% and extractable sugar % ranged between 8.97 and 13.8% for Betasana-Trio at 0.09 l fed^{-1} and Betanal MaxxPro at 0.5 l fed^{-1}. The highest sugar beet sugar yield resulted from the herbicidal treatment with Betanal MaxxPro or Tigro at 1.0 l fed^{-1}, which gave the greatest gross and extractable sugar yield fed^{-1} and exceeded the hand weeding treatment by 10.4 and 7.8%. Weed treatment with Betanal MaxxPro resulted in the highest contained the highest gross sugar %, extractable sugar %, the highest purity 83% and the lowest low soluble non-sugars (potassium, sodium and α-amino nitrogen content of beet). Data in Table 5 and Fig. 2 show that weed control treatments exhibited clear differences in sugar beet quality parameters, which affected sugar extraction. The highest sugar beet yield resulted from Tigro at 1.0 l fed^{-1} followed by hand weeding twice, which gave the greatest sugar yield fed^{-1}.

Discussion

The results of weed flora indicated that the dominant weed species were related to broadleaf. Several investigators reported that approximately 70% of weed species in sugar beet fields are mainly broadleaf annual such as redroot pigweed (*Amaranthus retroflexus*) (Weaver and Williams 1980; Schwizer and May 1993 and Heidari et al. 2007; Lobmann 2019).

Weed elimination in sugar beet was achieved by Betasana-Trio and Tigro herbicides as well as Select Super herbicide. These results indicated and confirmed that Betasana-Trio and Tigro herbicides are specified to broadleaved weeds. Similar tendency was recorded for the narrow-leaved weeds where these results indicated and confirmed that Select Super herbicide is specified to narrow-leaved weeds. Mousa et al. (2015) reported that all weed control treatments decrease significant various weeds categories than untreated check and hand hoeing twice was the most superior treatment on reducing the fresh weight of weeds species in both seasons, and gave significant effect on the second one only. Hand hoeing twice gave the highest significant percentage with Rumex dentatus and Chenopodium murale by 83 and 90%, respectively, compared to untreated control. Also, he added that the total broadleaf and total broadleaf and grassy weeds were significantly reduced by 54 and 91%, respectively, compared to untreated check in the second season. Our findings are consistent with those obtained by Attia et al. (2011), Vasel et al. (2012), Wujek et al. (2012) and Deveikte et al. (2015).

Regarding the effect of herbicidal treatments on sugar beet leaf pigmentation, the results indicated that although the mode of action of most of these herbicides is a classical photosynthesis inhibitor, they possessed higher selectivity and did not affect sugar beet leaf chlorophyll content; meanwhile, all of the treatments surpassed the control. Such superiority in chlorophyll content may be due to the lesser competition between sugar beet plants and the associated weeds as indicated in Table 3). The results emphasized that all the herbicidal treatments except Tigro at the lower dose did not affect sugar beet pigmentation of leaves. Chitband et al. (2014) reported that PSII inhibitor herbicide such as chloridazon controlled weeds at higher doses more than other herbicides (except of Portulaca oleracea) by 90 percent reduction in aboveground dry matter yield.

Applying Betanal MaxxPro, hand hoeing twice, Tigro at 1.0 l fed^{-1} and Betasana-Trio 0.9 l fed^{-1} produced high values of root yield t fed^{-1}. These treatments significantly increased root yield t fed^{-1}over the unweeded check by 79.4, 68.8, 42.9 and 33.9%, respectively. Such superiority of these treatments in increasing sugar beet yield characters may be due to the lesser coemption of weeds to sugar beet, especially at the early growth stages, which reflected on number and weights of the different species. Similar results were obtained by Soroka and Gadzhiev (2006) who reported that when sugar beet and weeds grow together 30 days after emergence of sugar beet, the root yield decreased by up to 45%. Also, Attia et al. (2011) and Majidi et al. (2011) reported that the use of herbicides may reduce yield losses, as herbicides can reduce the weed infestation. Mehmeti (2004) showed that using a combination of broadleaved herbicides caused weeds to be controlled and root yield to be increased. These results are in accordance with those recorded by Wujek et al. (2012), Mobarak et al. (2012) and Abou-Zied et al. (2017).

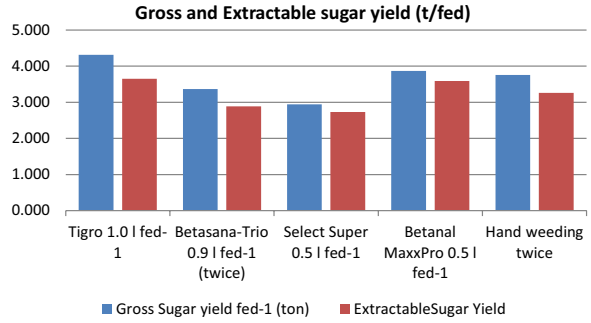

Fig.1 Effect of different weed control treatments on gross and extractable sugar yield fed^{-1} (t)

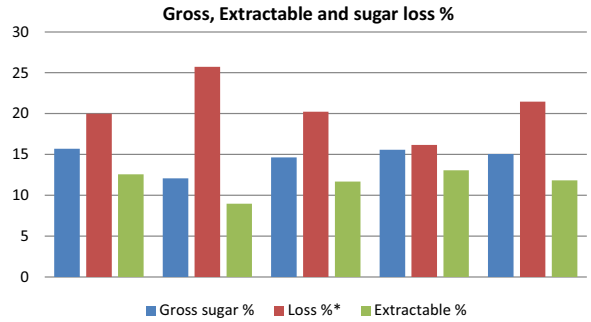

Fig. 2 Effect of different weed control treatments on gross and extractable sugar yield fed^{-1} (t)

The data of the effect of weed control treatments on sugar beet root quality exhibited clear differences in sugar beet quality parameters, which affected sugar extraction process. In general, although the weed treatment with Betanal MaxxPro contained the highest gross sugar %, it could not compensate the relatively lower yield to achieve the highest sugar yield fed^{-1}. It seems that α-amino-N component is related to sugar detracting, where it lowers the Qz % parameter. Sugar beet plants treated with Betanal MaxxPro possessed the maximum purity parameters (high Qz % and low soluble non-sugars (potassium, sodium and α-amino nitrogen content of beet). This resulted in the superiority of gross and extractable sugar yields fed^{-1}. In this respect, Dale et al. (2005) found that white sucrose produced per unit area did not differ among post-herbicide treatments and sugar and non-sugar contents were not affected by the herbicide treatments. It was reported that sugar yield values followed that of root yield because the herbicide did not have any influence on the amount of sugar beet root quality parameters (Dale et al. 2006).

Moreover, Dale et al. (2005) found that white sucrose produced per unit area did not differ among post-herbicide treatments and sugar and non-sugar contents were not affected by the herbicide treatments. Sugar yield values followed that of root yield because the herbicide did not have any influence on the amount of sugar beet root quality parameters (Dale et al. 2006). Mahmoud and Soliman (2012) indicated that sugar yield per feddan in the first season increased in five treatments (crus 2.5 kg fed^{-1} + handweeding, Betanal MaxxPro + hand hoeing, hand hoeing twice, crus 2.0 kg fed^{-1} + handweeding and crus 2.5 kg fed^{-1}) as they gave 5.4, 4.98, 4.73, 4.64 and 4.35 t fed^{-1}, respectively, with percentage from unweeded check 251.87, 232.02, 220.56, 216.33 and 202.64%, respectively. The unweeded check gave the least sugar yield per feddan (1.7 t fed^{-1}); also harness and crus 2.0 kg fed^{-1} gave lower sugar yield than the rest of treatments (2.64 and 2.84 t fed^{-1}, respectively) with percentage from unweeded check 155.15 and 166.79%, respectively.

Conclusion

Weed elimination in sugar beet was achieved by Betasana-Trio and Tigro herbicides as well as Select Super herbicide. Although the mode of action of most of the herbicides used is a classical photosynthesis inhibitor, they possessed higher selectivity and did not affect sugar beet leaf chlorophyll content. Applying Betanal MaxxPro, hand hoeing twice, Tigro at 1.0 l fed^{-1} and Betasana-Trio 0.9 l fed^{-1} produced high values of root yield t fed^{-1}. Sugar beet root quality exhibited clear differences in sugar beet quality parameters, which affected sugar extraction process. In general, although the weed treatment with Betanal MaxxPro contained the highest gross sugar %, it could not compensate the relatively lower yield to achieve the highest sugar yield fed^{-1}.

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Authors' contributions
EMA, MSA and IME designed and implemented the field trials. BBM statistically analyzed the data and contributed significantly to the conception and design of the study. EMA, MSA, BBM and IME shared in the interpretation of data and the drafting and revision of the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
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Not applicable.

Ethics approval and consent to participate
The authors declare that the work is ethically approved and consent to participate.

Competing interests
The authors declare that they have no competing interests.

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