AFFECTING THE DESIGN PARAMETERS OF RIDGER FURROW OPENER AND PLANTING METHODS ON SUGAR BEET YIELD AND WATER USE EFFICENCY

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(Manuscript received 2 April 2014)

Abstract

Design parameters of the ridger furrow opener directly affecting the furrow profile characteristics and the amount of applied water. Furrow-bed irrigation technique is usually used for water conservation, efficient fertilizer use and many other benefits. This study was to evaluate the impact of design parameters of the ridger furrow opener and planting methods on sugar beet yield and water use efficiency. Therefore, field experiments were conducted to (i) investigate the effects of share rake angles (20^o, 25^o and 30^o), opener wing angles (35^o and 45^o) and wing shapes (straight and curved) on the furrow profile characteristics, transverse scattering, draft force, and (ii) evaluate planting methods (i.e. ridges with 50 cm rows spacing and pair of rows on bed with 30, 35 and 40 cm rows spacing), the wing shape and angles on the percentage of emergence, sugar percentage, root and sugar yield, applied water and water use efficiency. The results showed that the curved shape and the wing angle of 45^o produced wider furrows than those produced by the straight shape and 35^o wing angle. Minimum transverse scattering was associated with the curved wing, wing angle of 35^o and share rake angle of 20^o. Increasing the share rake and wing angles increased the required draft force. The highest average values of root and sugar yields could be achieved by planting beet in beds with 30 cm rows spacing flowed by beds with 35 and 40 cm rows spacing, respectively. The lowest value of the water use efficiency was achieved by planting on ridges compared to the other planting methods. The maximum emergence percentage, root and sugar yields, sugar percentage and water use efficiency were associated with a wing angle of 45^o and the curved wing shape.

Keywords: *Sugar beet, power requirements, yield, furrow profile, applied water, bed planting.*

INTRODUCTION

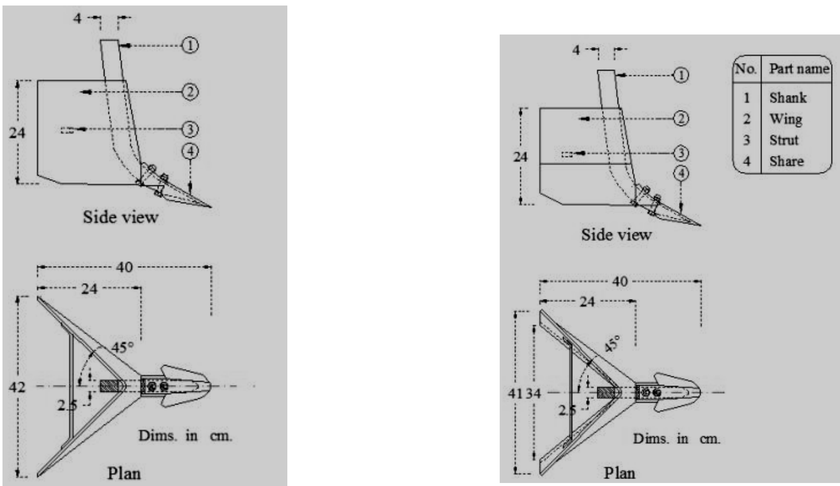
Optimum population of plants on well-spaced rows has been found to produce good yield and quality in most of the arable crops. Good plant stand gives a complete occupation of the available space, and plant can receive light from all sides, i.e., complete light interception, (Zahoor *et. al.,* 2010). Scott and Jaggard (1978) found a close relationship between solar radiation intercepted by a sugar beet crop and the yield. Egypt is considered as a country of water scarcity due to the low precipitation, high evaporation and temporal and spatial distribution of rainfall, and the land resources are limited (Abo-Shady *et. al.,* 2010). In such regions, bed planting is one of the most renowned techniques used for saving water, efficient fertilizer use and many other benefits. Bed planting technique has been tested for several crops*,* it significantly improved the relationship of soil-water, nutrient, and the root growth of plants (Ren *et. al.,* 2013). Chaudhry *et. al.,* (1994) reported that furrow bed system saved about 25-53% of water and increased the yield of cotton crop by 6-52% as compared to basin system. In addition to the water saving, bed planting also improves the efficiency of fertilizer, reduces weed infestation and reduces seed rate without sacrificing yield. Irrigation water consumption in ridge and furrow planting depends mainly on the wide of furrow and the furrow profile as well, (Hu *et. al.,* 1997). The design parameters of the furrow opener such as the share rake angle and wing shape and angle strongly affect the shape of the ridge profile. In addition, one of the most important parameters strongly affect the required draft force is the share rake angle. For better penetration of soil, the rake angle of the share should be ≥ 25^{o} to the ground (Abd El-Tawwab et al. 2007). However, Zhang and Araya (2001) reported that the draft force of a mold board plough had increased steeply when rake angle was more than 30^{o}. The rake angle of the furrow opener that gave a minimum specific draft for a lateritic sandy clay loam soil was 28 (Mathur and Pandey 1992) *,* while, Vashney and Patel (1988) reported that the minimum draft required for a cultivator shovel at different levels of soil moisture in a light soil was associated with 30^{o} share rake angle. Acvarshney *et. al.* (2006) investigated the effect of share rake angle of mould board plough and sweep on the draft force requirement in a clay soil .They reported that the minimum specific draft was found with rake angles ranged from 25^{o} to 29^{o} with the sweep at soil moisture content of 21%. The sweep angle also affects the draft requirement and the furrow profile*,* increasing share sweep angle increased the draft force (Fielke, 1988). In Egypt, sugar beets are grown on raised planting beds to facilitate furrow irrigation. The common arrangement of rows is a single row centered on beds 60 cm apart.

Therefore, the objectives of the current study were to: (i) Study the effect of some design parameters of furrow openers (e.g., share rake angle, wing angle and wing shape) on the furrow profile, seeds transverse scattering, and draft force requirements. (ii) Study the effect of planting methods (i.e., ridges and bed planting with different row-row spaces) on emergency, sugar parentage, root and sugar yield and water use efficiency.

MATERIALS AND METHODS

Experimental design

Two field experiments were conducted in a private farm at Kafer Elsheikh governorate, Egypt, (31° 8` N, 30° 41` E) in 1.75 hectare during agricultural season of 2011/2012. The field soil was mainly clay loam with a bulk density in the range between 1.31 and 1.44 g.cm^{-3}. Soil was prepared using chisel plough (7 shanks) two passes, disc harrow, and LASER leveling with 0.5 % slop. The first experiment was to evaluate the impact of some design parameters of furrow openers in a ridging unit on furrow profile, transverse scattering, and power requirements. These parameters are the share rake angles (20°, 25°, and 30°), wing angle (35° and 45°), and wing shape (straight and curved, Fig.1). Experimental treatments were laid out in split-split plot design with three rake angles as the main treatments, two opener's wing angles as the sub treatment and two wing shapes as the sub-sub treatment. These experiments were conducted in ridges 50 cm apart with the planter forward speed of 3.5 km.hr^{-1} and 15 cm ridging depth.



(a) straight (b) curved

Fig . 1. Shape of the opener wings

The second experiments were to evaluate four planting methods (ridges with 50 cm row space and beds having pair of rows on bed of 30, 35 and 40 cm distance between rows), two wing shapes (straight and curved), and two wing angles (35° and 45°). This is to investigate the effect of these parameters on emergence, sugar percentage, root and sugar yields, water applied and water use efficiency. The experimental plots were arranged in spilt- split plot design. The main plot was for the planting methods, the sub plot was for the wing angles and sub-sub plot was for the wing shape. In all experiments, different combinations of treatments were repeated three times (replicates). In the available conventional planters (e.g., Gaspardo Seminatrici SPA, Fig. 2(a)), the minimum distance between each two furrow openers is 60 cm. It is well known that reducing the distances between rows would increase the number of plants per unit area. Accordingly, Gaspardo Seminatrici SPA planter was modified at the workshop of Delta sugar Co., (Kafer Elsheikh Factory). Several pre trails have been made to adjust a relatively low distance between the ridges of the planter. The minimum distance could be obtained was 50 cm without affecting the ridges centerlines (location of dropping the seeds).

This modification was accomplished by fixing a steel beam (i.e., toolbar, 15 x 15 cm cross sectional area, and 0.7 cm thickness) in the front of the planter (Fig. 2 b). The ridger furrow openers were attached with this beam instead of the main planter frame in the conventional design. Three square tubes, each with cross sectional area of 8 × 8 cm and 0.6 cm thick, were welded and used to fix the hitch points with the beam (Fig. 2b). The modified toolbar can be simply fixed to the planter and makes it available to be used for other crops by separating this unit when needed. In addition, curved wing shape was designed fabricated (Fig. 1 b) to compare with the conventional wing shape (i.e., straight). Seeds of sugar beet cultivar (Multigerm Montbuanco) were sowed in 13th September 2011 and the crop harvesting was done in 17th April 2012. Fertilizers were added according to the technical recommendation of the Ministry of Agriculture at rates of 214 kg N, 36 kg P_2O_5 and 238 kg K_2SO_4 per hectare. Nitrogen fertilizer was applied in two equal doses before the first and the second irrigations. Phosphorus was broadcast before planting as Super Phosphate (15.5% P_2O_5). Potassium was applied by topdressing in one application of Potassium Sulphate (48% K_2O) before the first irrigation. Furrow irrigation of sugar beet was used and controlled by the siphon method FAO (1974) and irrigation water was applied every 21 days (Irrigation intervals).

(a) (b)

Fig . 2. Photo of the planter before modification (a) and after modification (b).

Experimental measurements

During executing these experiments the following indicators have been measured:

(i) Furrow profile characteristics were measured by using a pin meter that was designed according to Römkens *et. al.,* (1986) and Wagner and Yi`ming, (1991). This meter is a row of probes holed in a horizontal rectangular steel bar, spaced at 5 cm intervals*,* the props designed to slide up and down into the holes of the bar to make their tips just to touch the soil surface. Accordingly, the pines positions were recorded manually, and then characteristics of each furrow profile were determined.

(ii) The transverse scattering of seeds placement was determined statistically by estimating the standard deviation of the distances between each seed and the row centerline. Thus, the slandered deviation (Std, cm) is given by:

$$\mathrm{Std} = \sqrt{\frac{\Sigma X^2 - (\Sigma X)^2 / n}{n - 1}} \quad \text{.......} (1)$$

Where X is the distance between the seed and the row centerline in cm and n is the number of observations.

(iii) Rolling resistance and draft force to determine the draft force (F, kN) that is required for the planting operation, two tractors were used*,* one is to hang-up and pull the planter and the other is to pull both (the planter with the tractor). A hydraulic dynamometer was fixed between the two tractors to measure the drawbar pull (DF, kN) during operation. Ten readings were recorded for each treatment and the mean value was obtained. The rolling resistance (RR, kN) of the tractor with the planter was determined at no load (lifted position) by the dynamometer methods at sowing speed. The net draft force (F, kN) was estimated as:

F = DF – RR .... (2)

(iv) The emergence percentage ($G_{p,\ \%}$) was estimated by accounting the number of plants (P) and the number of delivered seeds (S) for each treatment. This was performed for the 2 central rows of each treatment and after 25 days from sowing. Accordingly, G_p was calculated as:

$G_p = P/S \times 100$ .... (3)

(v) The amount of applied water (IW, $m^3\ ha^{-1}$) for each treatment was measured by using a siphon tubes. Siphon tubes, 2 m length and 50 mm diameter, were calibrated by using a container and a stopwatch to calculate the flow rate of the tubes. The inflow rate was constant during the irrigation periods of the treatments. Water use efficiency (WUE, $Mg\ m^{-3}$) was calculated according to Jensen, (1983) as:

WUE=Y/IW.. (4)

where Y is the root yield, in $Mg\ ha^{-1}$, was estimated for the central three ridges of each plot .

(vi) The sugar yield ($Mg\ ha^{-1}$) was estimated as the percentage of sucrose multiplied by root yield (Y). The percentage of sucrose was estimated for the fresh harvested roots by using an Automatic Sugar Polarimeter as described by McGinnus, (1982) at Delta Sugar Co. Ltd. , (El-Hammol, Kafr El-Sheikh Governorate, Egypt).

RESULTS AND DISCUSSION

Two field experiments were conducted, the first was to investigate the effect of share rake angle, wing shape and wing angle on the furrow profile, transverse scattering and draft force requirements, the second was to evaluate the effect of planting methods, wing shape and angle on seedling emergency, sugar percentage, root and sugar yield, and water use efficiency.

Effect of share rake angle, wing shape and wing angle on:

Characteristics of furrow profile

The furrow profile at different share rake angles and wing angles as well as wing shape was illustrated in Figs (3 and 4). The general trend of furrow profiles shown in Figs. (3 & 4) indicated that the furrow depth was proportional to the share rake angle. The highest furrow depth associated with the rake angle of 30°. This trend was due to the increase of the share penetration into the soil by increasing the share rake angle. These results agree with those reported by Varshney *et. al.,* (2006) and Abd El-tawwab et al, (2007). For all rake and wing angles used in this study, the edge of the bed and the depth of furrow performed by the curved wing were higher than those performed by the straight wing. This may attributed to the collapse the soil inside furrows performed by the straight wings immediately after it formed. Increasing wing angle tends to increase the furrow width due to increase the soil cross-sectional area that moves in the front of the share having a wing angle of 45° compared to wing angle of 35° for all the share rake angles and wing shapes.

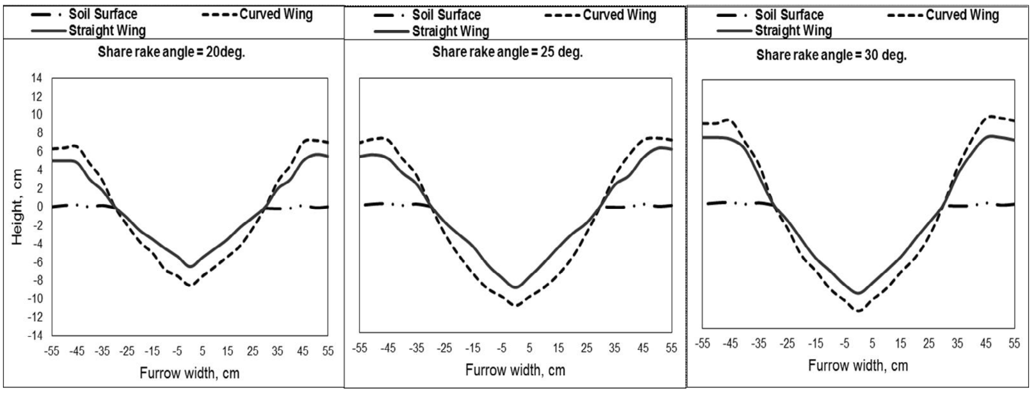


Fig. 3. Furrow profile as influenced by share rake angle and wing shape for a wing angle of 45°.

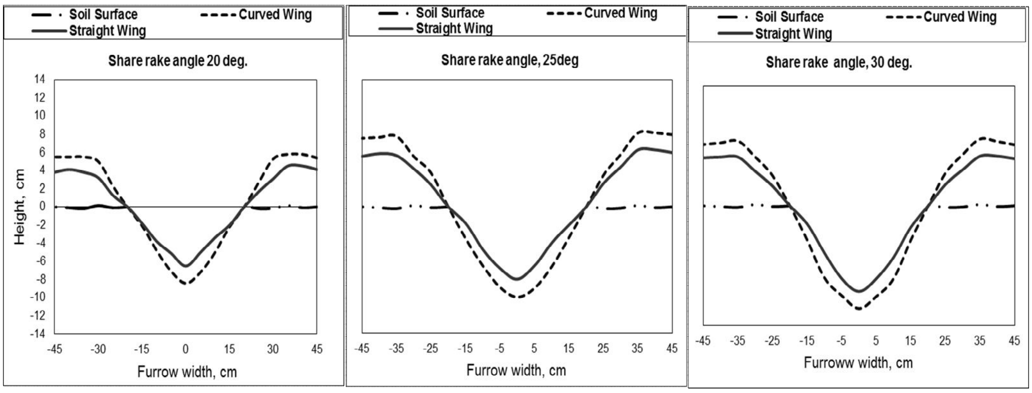


Fig . 4. Furrow profile as influenced by share rake angle and wing shape for a wing angle of 35° .

Seeds transverse scattering

Standard deviation tells the dispersion of seeds from the optimum location (i.e., the row centerline). The standard deviation at different share rake angles, wing angles and wing shapes are presented in Fig (5). At given wing angles and shape, the standard deviation was observed to increase with increasing share rake angle. For example, a decrease in the share rake angle from 30 to 20 caused a drop in the standard deviation from 2.9 to 2.04 cm at a wing angle of 35° and straight wing shape. This attributed to increase the soil movement and machine vibration as affected by increasing the share rake angle, this makes the seed to move with the soil away from the ridge centerline. For all share rake angles and both wing shapes, the maximum standard deviation occurred when the wing angle was 45°, and the minimum standard deviation could be achieved when the wing angle was 35°. This may be attributed to the stability of seeds on the ridge in case of 35° wing angle was higher than that of 45° wing angle due to seed dropping down away from edge of the ridge. Also, the lower values of the standard deviation were recorded with the curved wing compared to the straight wing for all wing and rake angles.

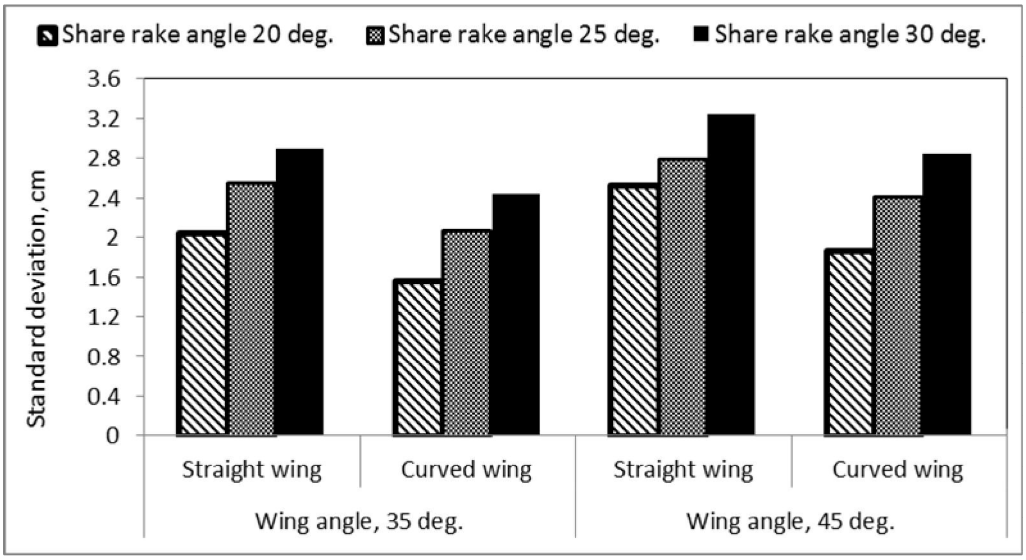


Fig .5. Effect of share rake angle, wing angle and wing shape on standard deviation of seeds scattering from the row centerline, cm

Draft requirements

Data of the net draft force required for the planter as affected by the different parameters considered is shown in Fig. (6). The minimum net draft was found to be associated with the rake angle of 20°at the different wing shapes and angles. Increasing the rake angle to 30° was observed to increase the required net draft force. These results were in agreement with those obtained by Abd El-tawwab et al (2007). Increasing wing angle tends to increase the net draft force due to the increase of the cross sectional area of the moving soil in the front of furrow opener and the resistance force as well. It can be seen from Fig. 6 that the highest values of the net draft forcers were recorded with the curved wing compared to the straight wing at all rake and wing angles due to increasing the frictional surface area of the curved wing compared to the straight wing.

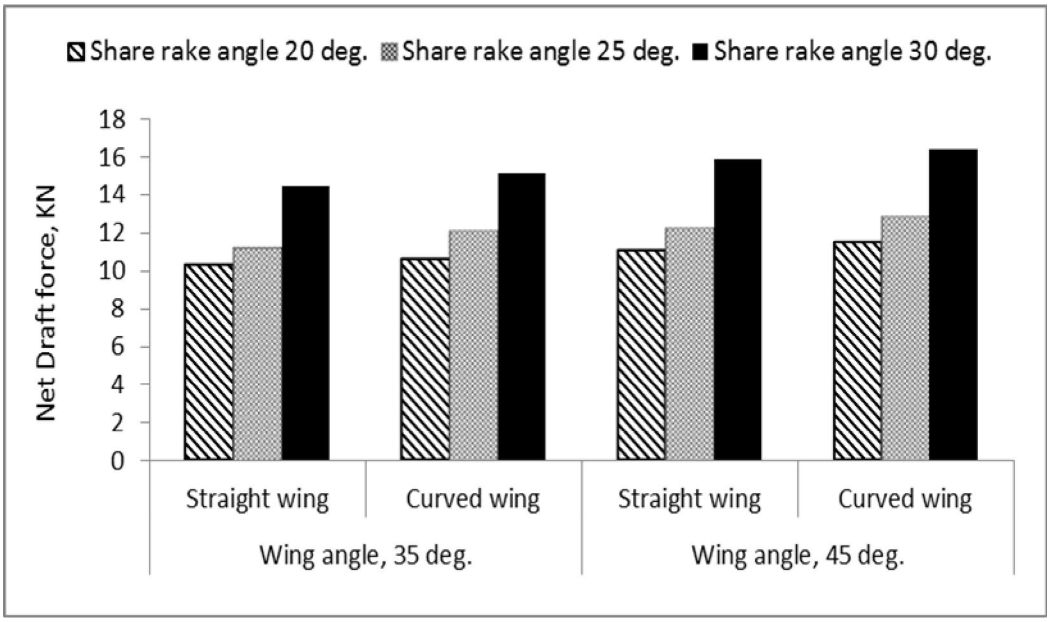


Fig . 6. Effect of share rake angle, wing angle and wing shape on net draft, kN.

Effects of planting methods, wing shape and wing angle on:

Emergence percentage

The statistical analysis indicated that the planting methods had no significant effect on the emergence percentage (Table 1). However, the germination percentage varied significantly ($P < 0.01$) under different wing angles and shapes (Table 1). The average emergence percentages under different planting methods, wing shapes, and angles are presented in Table 2. Wing angle of 45^{o} gave a higher emergence (89.22 %) as compared to 35^{o} wing angle (87.81%). A wider furrow increases the water flow, therefor water could not reach at ridge top which produced a warm bed area that enhances the germination percentage. The curved wing produced a higher germination percentage than the straight wing (Table 2). This may attributed to collapse of soil inside the furrow which impedes the water flow and increases its level inside the furrow.

Table 1. Two way analysis of variance for different sugar beet parameters.

SOV	Seed emergence, %	Root. yield, $Mg.ha^{-1}$	Sugar percentage., %	Sugar yield, $Mg.ha^{-1}$	Applied water, $m^3.ha^{-1}$	Water use efficiency, $Mg\ m^{-3}$
F- value						
Planting method (M)	2.76	51.98**	26.80**	37.72**	76.98**	386.96**
Wing angle (A)	50.13**	3.13 NS	24.91**	7.60*	111.36**	767.41**
Wing shap (S)	30.62**	6.87*	9.78**	5.60*	181.41**	1216.15**
M * A	0.68 NS	0.11 NS	0.031 NS	0.04 NS	0.44 NS	15.06**
M* S	2.81 NS	0.07 NS	0.18 NS	0 NS	0.34 NS	13.41**
S * A	0.99 NS	0.06 NS	0.6 NS	0.17 NS	0.81 NS	76.87**
M * A *S	0.7 NS	0.07 NS	0.04 NS	0.03 NS	1.37 NS	11.43**

*p < 0.05 **p < 0.01, NS is not significant

Root yield

planting methods showed a highly significant effect (P<0.01) on the root yield (Table 1). Sugar beet planted in beds with 30 cm rows spacing produced maximum mean root yield (75.57 Mg ha^{-1}) followed by beds with 35 cm rows spacing (71.45Mg ha^{-1}). On the other hand, the results of LSD test indicated that the differences between planting sugar beet in ridges, 50 cm apart, and planting on beds with 40 cm rows spacing was not significant (Table 2). Previous studies focused on three agronomic factors affecting the sugar beet yield (i.e., row spacing, hill spacing and plant population). In the current study, the hill spacing was maintained constant and the rows spacing was varied, this produced different plant population. Accordingly, plants population in beds was more than those in ridges. The same findings were obtained by Zahoor et al (2010). Considering the effect of wing shape on the root yield, the statistical analysis showed that the root yield was significantly affected by wing shape (P<0.05). It is evident from Table 2 that the curved wing was associated with the high value of root yield (72.175 Mg ha-1) compared to the straight wing (70.745 Mg ha-1). This was attributed to increase the number of plant per unit area as a result of increasing the emergence percentage. The wing angle had no significant effect on the root yield (Table 2).

Table 2. Mean values of sugar beet parameters as affected by planting methods, wing shape and angle.

Planting methods	Seed Emergence, %	Root yield, Mg ha^{-1}	Sugar Percentag, %	Sugar yield, Mg ha^{-1}	Applied water, m3 ha^{-1}	Water use efficiency, Mg m^{-3}
Beds with 40 cm rows spacing	88.8 a	68.98 a	18.92 a	12.98 a	7267.9 a	9.75 a
Beds with 35 cm rows spacing	88.42 a	71.45 b	18.83 a	13.40 a	7455.3 a	9.80 a
Beds with 30 cm rows spacing	88.76 a	75.57 c	18.79 a	14.13 b	7663.6 a	10.16 b
ridges 50 cm a part	88.1 a	69.29 a	17.02 b	11.74 c	9716.4 b	7.26 c
LCD 0.05	1.296	1.458	0.613	0.565	452.46	0.234
Wing Angle, degree						
35	87.81 a	70.75 a	17.950 a	12.62 a	8710.5 a	8.303 a
45	89.22 b	71.90 a	18.83 b	13.5 b	7341.1 b	10.18 b
LCD 0.05	0.418	1.421	0.359	0.679	249.54	0.143
Wing Shape						
Straight	87.967 a	70.475 a	18.115 a	12.68 a	8899.7 a	8.303 a
Curved	89.067 b	72.175 b	18.667 a	13.44b	7151.9 b	10.18 b
LCD 0.05	1.071	0.7006	0.598	0.3868	470.93	0.1623

Sugar percentage and yield

Sugar percentage was highly significantly ($P<0.01$) affected by planting methods (Table 1). The planting of sugar beet on ridges, 50 cm apart, was associated with low percentage of sugar compared to the other planting methods. This may attributed to the increase of the moisture content of the soil in the root area as affected by the presence of water on both sides of the ridge. On the other hand, for sugar beets planted on beds with different rows spacing there is no significant difference in sugar percentage between the different rows spacing on beds. The planting methods had a highly significant effect on sugar yield (Table 1). Sugar beet planted on beds with 30 cm rows spacing produced highest sugar yield (14.13 Mg ha^{-1}), while, the lowest sugar yield (11.74 Mg ha^{-1}) was associated with beets planted in ridges. There is no significant effect of beets planted on beds with 35 and 40 cm rows spacing on sugar yield. In general, the wing shape and angle had a significant effect ($P<0.05$) on the sugar yield (Table 1). The use of the curved wing and wing angle of 45^{o} significantly increased the sugar percentage and yield compared to the straight wing and wing angle of 35^{o}.

applied water

The results of applied water to the sugar beet as affected by the planting methods, wing shape and wing angle were presented in Table 2. The statistical analysis indicated that the applied water was highly significantly affected by the planting methods, wing shape and angles. Planting beet on ridges resulted in a higher amount of irrigation water applied compared to planting beet on beds. This may attributed to the fact that the number of furrow in case of ridges was more than that in case of beds which requires more water to fill. The same findings were reported by Chaudhry et al (1994). LSD test shows that there were no significant differences between the amounts of water applied to the beds with different row spaces (Table 2). Using the curved wing and wing angle of 45^o led to decrease the amount of water applied compared to the straight wing and 35^o wing angle because the furrows profiles produced by the curve wing and 45^o wing angle were wider than that produced by the straight wing and 35^o wing angle.

Water use efficiency (WUE)

Water use efficiency was high significantly affected by the planting methods, wing angle and shape. Planting the beet on beds with 30 cm distance between rows induced higher water use efficiency than the other planting methods. On the other hands, the planting of sugar beet on ridges was associated with low values of water use efficiency compared to planting on beds. Data presented in Table 2 shows that the water use efficiency for the beet planted on beds was not significantly affected by changing the space between rows from 35 cm to 40 cm. The maximum values of water use efficiency were associated with the curved wing and the wing angle of 45^o compared to straight wing and wing angle of 30^o. This may attributed to increasing the root yield and decreasing the amount of applied water.

CONCLUSION

Based on the results obtained from this study, specific conclusions could be summarized as follows:

- The curved wing angle of 45^o wing angle and rake angle of 30^o resulted in a wide furrow profile than the other parameters tested in this study.
- The minimum transverse scattering (std, 1.6 cm) was associated with the share rake angle of 20^o, wing angle of 35^o and curved wing shape.
- Increasing the share rake from 20 to 30^o and wing angles from 35 to 45^o resulted in an increase in mean values of net draft force requirement by 42 and 8.2 %, respectively.

- The planting methods showed highly significant effects on the sugar percentage, sugar and root yields, amount of applied water, and water use efficiency.
- The highest values of the emergence percentage (89.22%), root and sugar yield (71.90 and13.5 Mg ha^{-1}, respectively), sugar percentage (18.83%), and water use efficiency (10.18 Mg m^{-3}) were achieved with the wing angle of 45^o compared to the wing angle of 35^o.
- Curved wing caused an increase in the emergence percentage, sugar percentage, sugar and root yields, and water use efficiency, while decreased the amount of irrigation water applied.

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تأثير العوامل التصميمية لسلاح وحدة التخطيط وطرق الزراعة على إنتاجية وكفاءة استخدام المياه لمحصول بنجر السكر

سامي عبد الجيد مرعي

معهد بحوث الهندسة الزراعية، مركز البحوث الزراعية، ص ب ٢٥٦، دقي، جيزة، مصر

تهدف هذه الدراسة الى دراسة تأثير العوامل التصميمية لسلاح وحدة التخطيط لألة زراعة بنجر السكر وطرق الزراعة على إنتاجية وكفاءة استخدام المياه لمحصول بنجر السكر. تم تعديل الة الزاعة (جاسباردو) لتقليل المسافة بين الخطوط لتكون ٥٠ سم بدلاً من ٦٠ سم كما تم تصنيع جناح منحني لسلاح الخطاط لمقارنتة بالجناح المستقيم (الجناح الأصلي) وأجريت عمليات التعديل بورش مصنع بنجر السكر بالحامول – شركة الدلتا للسكر. أجريت التجارب الحقلية بإحدى المزارع الخاصة بمركز دسوق محافظة كفرالشيخ على مرحلتين الاولى كانت لدراسة تأثير العوامل التصميمية لسلاح وحدة التخطيط والتي اشتملت على:

- زاوية اختراق السلاح (٢٠، ٢٥، ٣٠ درجة).
- شكل الجناح (جناح منحني ومستقيم)
- زاوية الجناح مع المحور الطولي للسلاح (٣٥، ٤٥ درجة)

وتأثير ذلك على كل من شكل الخط ، التشتت العرضي للبذور و قوة الشد المطلوبة.

والمرحلة الثانية اشتملت على:

- طرق الزراعة (الزراعة على خطوط المسافة بينها ٥٠ سم، خطين على مصاطب المسافة بين الخطوط كانت ٣٠، ٣٥، ٤٠ سم)
- شكل الجناح (جناح منحني ومستقيم)
- زاوية الجناح مع المحور الطولي للسلاح (٣٥، ٤٥ درجة)

وتأثير ذلك على نسبة الإنبات، نسبة السكر ، انتاجية الجذور والسكر، كمية المياه المضافة، كفاءة استخدام المياة.

وكانت اهم النتائج التي تم الحصول عليها كما يلي:

- ادى استخدام الجناح المنحني وزاوية الجناح ٤٥ درجة الى زيادة عرض الأخدود وكذلك زيادة قوة الشد المطلوبة وذلك لجميع زوايا إختراق السلاح في حين ان اقل نسبة تشتت عرضي (الخطأ القياسي للمسافة بين موقع البذور ومحور الخط) تم تسجيله مع الجناح المنحني وزاوية الجناح مع المحور الطولي للسلاح ٣٥ درجة.
- زيادة زاوية اختراق السلاح ادت الى زيادة عمق الاخدود وقوة الشد المطلوبة وكذلك نسبة التشتت العرضي.
- اعلى انتاجية لمحصول الجذور والسكر تم الحصول علية بزراعة بنجر السكر على مصاطب مع مسافة بين الخطوط ٣٠ سم في حين اقل انتاجية كانت مع الزراعة على خطوط.
- استخدام الجناح المنحنى لسلاح الخطاط وزاوية الجناح ٤٥ درجة ادت الى زيادة نسبة الإنبات، انتاجية الجذور والسكر، نسبة السكر، وكفاءة استخدام المياة.
- لنفس نوع التربة التي اجريت عليها الدراسة ينصح باستخدام الجناح المنحني مع زاوية ٤٥ درجة مع المحور الطولي للسلاح وزاوية اختراق للسلاح ٢٥ درجة. كما توصي الدراسة بزراعة بنجر السكر على مصاطب المسافة بين الخطوط ٣٠ سم.