Effect of Plant Density, Potassium Fertilization and Foliar Application with some Micro-Element Nutrients on the Yield and Quality of Sweet Sorghum

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ABSTRACT

Two field experiments were conducted at the Sabahia Research Farm in Alexandria Governorate, Egypt during **2009 and 2010** summer seasons to study the effect of plant density (25, 30 and 35cm), potassium fertilization (0 and 50kg /fad)and some micro-elements, as foliar application with chitocare after 45 days and 90 days from planting, on yield and quality of sweet sorghum (Sorghum bicolor, L.) The treatments were arranged in split-split plot design in three replications.

The most important results were summarized as follows. Plant density at 35 cm led to attain the highest values of leaf area index, stalk yield (kg), weight of syrup and T.S.S %. Potassium fertilizer level (50kg k_2O/ fad) gave the highest leaf area index. Foliar spraying with chitocare showed supevority of leaf area index, stalk yield, weight of syrup and T.S.S % and juice quality parameters. As for, the interaction between the potassium fertilizer level and foliar spraying chitocare had significant effect for T.S.S %.

INTRODUCTION

The economic importance of introducing sweet sorghum cultivation could be realized from the saving of about 250000 tons of sugar that go to syrup manufacture. Currently, the annual consumption of sugar in Egypt amounts to 1.991* million tons. Approximately 72 % of that amount is produced locally from sugarcane and sugar beet, while the rest is imported. To reduce the gap between consumption and production we should use sweet sorghum. Many factors affect growth, yield and quality of sorghum varieties. Regarding plant density is also an important agronomic factor affecting yield and syrup quality of sweet sorghum. Also some micro elements provide sweet sorghum with food which it needs because new reclaimed soil is poor in nutrient elements.

Rosenthal *et al.* (1993) reported that leaf area index tended to be higher with the higher densities.

Mailikarjun *et al* (1997) indicated that the best values of extractable syrup, sugar content and brix value and millable stalk yield was higher at the density of 660000 plants/ha. **Mahmoud *et al* (1999)** found that increasing plant density decreased stalk diameter, stalk weight, purity% and reducing sugars% as well as sucrose % and brix value, while stalk and syrup yields were increased. **Ramadan (2004)** revealed that the wider space (30cm) between hills produced the highest stalk diameter, stalk length, brix value, and sucrose % as well as reducing sugars and purity percentages. On the other hand, stalk weight, stripped stalk yield, syrup yield (gallon/fad) and total syrup sugar yield were increased when sweet sorghum plants were grown at 25 cm between hills. **Abd El-Latif (2005)** showed that hill spacing had insignificant effects on stalk weight, stalk yield, total soluble solids and sucrose percentage, but a significantly affected leaf area index and purity percentage at 30 cm hill spacing.

Potassium has a great influence on syrup quality and syrup production. **Ingawale *et al* (1992)** working on sugarcane, obtained the highest brix value and sucrose content with application of 55 kg K_2O/ha Also, they attained the highest sugarcane dry matter (DM) yield (38.1 tons/ha) with application of 110 kg K_2O/ha.

El - Taweel (1994) found that potassium application caused a significant increase in leaf area index, stalk yield, syrup yield, syrup yield, total soluble solids and sucrose percentage of sorghum in the two seasons. **Amrutsagar and Sonar (1999)** showed that the highest grain yield (4.5t/ha) and straw yield (5.7t/ha) of sorghum were produced by application of 120 kg K_2O/ha. **Pholsen and Sornsungnoen (2004)** reported that any increase of K_2O rates significantly increased most growth parameters of sorghum plants.

Concerning foliar application of micro element nutrients, **Azim *et al* (1994)** indicated that P- application showed an antagonistic effect on zinc concentration. Zinc in plants is mainly involved in sweet sorghum. **Hussein and Faiyad (1996)** found that dry matter yield increased with increasing the rate of Zn application. Zn uptake increased with increasing the rate of Zn application and was the highest with 7.5 mg $ZnSo_4$. Moreover, plant height, LAI and NAR increased with increasing Zn rates. **Zeinab *et al* (2002)** showed that addition of Zn, P and inoculation with (VAM) led to increase in all yield parameters (total plant, forage, stalk, baggas, syrup and syrup weights

(ton/fad) as well as syrup and syrup extraction percentage), yield components, (plant height, number of internodes and stalk diameter), total soluble
solids (TSS), sucrose percentage (S %) leaf area index (LAI) and net assimilation rate (NAR).

The objective of this investigation was to study the effect of plant density, potassium fertilization and foliar application with some microelement nutrients, in form the of chitocare, on the yield and quality of sweet sorghum.

MATERIALS AND METHODS

Two field experiments were conducted at the Sabahia Research Farm in Alexandria Governorate, Egypt during the summer seasons of **2009 and 2010,** to study the effect of plant density, potassium fertilizer and foliar application of some micro-elements foliar the in form of chitocare, on yield and quality of sweet sorghum (Sorghum vulgare, L.) Sowing dates were on 10 and 15 of June in **2009 and 2010** seasons, respectively.

Asplit-split plot design in three replications were followed. The foliar application levels were arranged in the main plots and the potassium level: 0 and 50 kg k_2O/ fad were arranged in the sub-plot where as the plant density (25, 30 and 35) were randomly distributed in the sub: sub plots.

1-Chitocare (nutrient solution).

Chitocare as nutrient solution was applied at a rate of 200 times at two doses, one after 45 day from sowing and the other after 90 day from sowing. Chitocare fertilization treatments were as follow:

1- Control treatment (distilled water without addition of chitocare)
2- One spray at 45 days from sowing at a rate of 200 times.
3- Two spray at 45, and 90 days from sowing at a rate of 200 times.

Chitocare: is a plant growth regulator that improves the yield, health and vigor of plant. Chitocare contains chitosan oligomers, and chelated elements (1000N, 500K, 500 B, 100 Fe, 100 Zn, 50M, 50 Cu and 50Pr) ppm

Table (1): Physical and chemical properties of the experimental soil for the two 2009 and 2010 seasons.

Seasons	2009	2010
	Mechanical analysis	Partial soil distribution:
Sand %	37.9%	37.0%
Silt %	19.2%	20.0%
Clay %	42.9%	43.0%
Soil texture	clay loam soil	clay loam soil
	Chemical analysis	
PH	8.16	8.17
EC (ds/m)	5.68	5.70
Mg++	3.70	3.66
Na+	5.00	5.06
Ca++	6.86	6.72
K+	0.38	0.33
Cl⁻	2.79	2.73
Co3⁻ +Hco3⁻	1.96	1.91
Available P (mg/kg soil)	3.12	3.00
Total nitrogen	0.15	0.12
Organic Matter %	1.37	1.28

The area of the sub sub-plot was 15 square meters (3m width × 5m length) conraing 5 ridges 60cm apart. Hills were thinned to, one sweet sorghum plant per hill. The first and the fifth ridges were left as borders. Phosphorus (150 kg P_2O_5/fad) was applied at the sowing date (the previous crop was sugar beet).

The normal agronomic practices were done as recommended. At 70, 90, 110 days after sowing and at harvest, a sample of ten random guarded plants from the two center rows

was taken to determine the following traits.

2-Potassium fertilization

K fertilization treatments were applied as potassium sulphate (48% K_2O) at one dose just before the 3th irrigation time (50 days from sowing). Potassium fertilization treatments were applied as follow:

1- 0 Kg. K_2O / fad (control).
2- 50 Kg. K_2O / fad.

3-Plant density.

Three hill spacings were studied:

1- 25 cm between hills
2- 30 cm between hills
3- 35 cm between hills

The normal agronomic practices were done as recommended. At 70, 90, 110 days after sowing and at harvest, a sample of ten random guarded plants from the two center rows was taken to determine the following traits.

A- Growth attributies:

a- Leaf area index: (LAI): Calculated using the formula outlined by **Watson (1958).**

Where: LAI= unit leaf area / unit ground area.

Unit leaf area = leaf area x No. of leaves/plant.
Leaf area = leaf maximum width x leaf length x 0.75 according to **Stickler *et al* (1961).**

B- Stalk yield and its components:

a- Single stalk weight was determined by dividing stalk yield per plot/number of stalks per plot (ton/fad).

b- Weight of syrup

c-100- seed weight (gm). Was estimated from weight 3sample.

C- Syrup quality traits:

a-Total soluble solids (T.S.S): Estimated by using hand refractometer.

b-Sucrose percentage: Determined by using direct POLARIZATION METHOD AS DESCRIBED BY **DE WHALLEY (1964).**

STATISTICAL ANALYSIS:

Data were subjected to statistical analysis according to **Snedecor and Cochran (1967).** The treatment means were compared by using L.S.D test of significant at 0.05level of probability.

RESULTS AND DISCUSSION

Growth attributies

a- Leaf area index

Data in Table (2) show that foliar spraying with chitocare twice (at 45 and 90days) was significant effect on leaf area index in the two seasons. These results were similar to those of **Hussein and Faiyad (1996).**

Also, the same Table (2) showed that potassium fertilization treatment at rate of 50kg/fad significantly affected for leaf area index in all growth periods. These results are in agreement with finding of **El – Taweel (1994).**

Regarding the plant density was a significant effect on leaf area index at all growth period of 70, 90, 110 days after sowing and at harvest in the two seasons where the 35cm space between hills gave the maximum values of leaf area index at these growth periods, for(6.71, 7.15, 7.66 and 8.13) as well as(7.01, 7.05, 7.32 and 7.83) in the first and second season, respectively. In this connection, **Rosenthal *et al.* (1993)** indicated that leaf area index tended to be higher for the higher densities.

The all interactions first and second order in both seasons were not significant at all growth periods for leaf area index, indicating that each factor was acting independently with respect to that trait.

Stalk yield and its components

a- Stalk yield

Data presented in Table (3) showed that spraying chitocare twice (at 45and90days) gave the maximum values of stalk yield in all growth periods in the two seasons, whereas, the lowest values were obtained when plants were not treated with chitocare. **Zeinab *et al* (2002)** showed that addition of Zn, P and inoculation with mycorhizae fungi (VAM) increased all yield components, (plant height, number of internodes and stalk diameter).

Regarding k-fertilization it could be noticed that no significant difference was found between 0 kg and 50kg/fad. Of potassium fertilizer over all the growth periods in both seasons. However, **El – Taweel (1994)** found that potassium application caused a significant

increase in total yield only in the second season.

Plant density of 35cm between plants significantly increased stalk yield in all growth periods at 70, 90, 110 day after sowing and at harvest, where it gave the highest values of weight of plant compared to the other spacings in the two seasons. The increase in stalk yield/fad by increasing plant density may be due to inter plant at higher competition for nutrient, water and densities. **Mahmoud *et al* (1999)**. They found that increasing plant density decreased stalk weight.

No significant interactions due to the first order interactions of (ch×k), (d×ch) and(k×d) as well as the second order interaction of (ch×k×d) were found at all growth periods in both seasons, indicating that each factor affected

stalk yield independently.

b- Weight of juice, 1000- grain weight

Data presented in Table (4), showed that spraying chitocare twice (at 45and90days) had significant effect on weight of juice and 1000- grain weight in the two seasons. These results are in the same line with those repc~ed by **Zeinab *et al* (2002)** who showed that addition of Zn, P and inoculation with (VAM) increase all yield parameters (total plant, forage, stalk, syrup and syrup weights)

Result revealed that potassium fertilization at rate of 50kg/fad affected significantly of 1000- grain weight, but affected no significantly on weight of juice and in both seasons. These results could be attributed to the important role of potassium in physiological process in plant such as translocation of carbohydrates of assimilation for the stalk to the underground part root **El – Taweel (1994)** found that potassium application caused a significant increase in juice yield and syrup yield.

It was evident from the data presented in Table (4) that plant density at 35cm between plants significantly affected weight of juice compared with the other distances between plants but no significantly affected 1000- grain weight in both seasons. **Abd El-Latif (2005)** showed that, concerning the factor of hill spacing, 25 cm had no significant effect on syrup yield.

The first order interactions of (ch×k), (d×ch), (k×d) and second order interactions (ch×k×d) were not significant with regard to weight of juice in the two seasons.

Syrup quality traits:

a- Total soluble solids (T.S.S)

Concerning chitocare nutrients in table (5), the highest

significant effects were found for spraying plants with chitocare twice (at 45and90days) where this treatment gave the maximum values in both seasons. These results are in the same line with those reported by **Zeinab *et al* (2002)** who noticed that total soluble solids (TSS) was increased with application of Zn, P and inoculation with VAM.

It could be noticed that potassium fertilization treatment at the rate of 50kg/fad had significantly increased TSS at harvest in both seasons. These result agree with those reported by **El – Taweel (1994)** who found that potassium application did not affect T.S.S.

Significant differences in T.S.S were found due to hill spacings at harvest in the two seasons of 2009 and 2010, as shown in Table (5) showed that the effect of hill spacing on total soluble solids percentage was insignificant in both seasons 2009 and 2010. These results were similar with the findings of **Mailkarjun *et al* (1997)**.

All interactions of (d×ch), (k×d) and (ch×k×d) were not significant for T.s.s trait at harvest, except the interaction of (ch×k) which was significant, it means that potassium fertilization and chitocare treatment acted dependently for T.S.S trait during harvest in both seasons of 2009 and 2010. T.S.S was at the maximum value under the high dose of potassium 50kg/fad .Also spraying chitocare twice at (45and90days) among growth periods in two seasons, minimum values of T.S.S were obtained when plants were untreated with k fertilization fertilization of (and foliar spray with chitocare) in the two seasons of 2009 and 2010.

b-Sucrose percentage in juice, sucrose percentage in syrup, weight of syrup

Data presented in Table (6) showed that chitocare nutrient, the highest values of sucrose% in juice, sucrose % in syrup, weight of syrup were attained from spraying chitocare twice (at 45and90days) in both seasons. These results are in the same line with those reported by **Zeinab *et al* (2002)** who noticed that sucrose percentage was increased with application of micronutrients and VAM.

Potassium fertilization treatment at rate of 50kg/fad gave the significantly highest values of weight of syrup. Mean while, the lowest ones were obtained from the control treatment in sucrose% in juice, sucrose% in syrup in the two seasons. **El – Taweel (1994)** found that potassium application caused a significant increase in sucrose percentage.

Refering to plant density had no significant effect in harvest with regard to sucrose% in juice, sucrose% in syrup, weight of syrup in the two seasons. These results are in accordance with the finding of **Abd El-**

Latif (2005) with regard to sucrose%.

The first order interactions of (k×d), (ch×d) and (ch×k), as well as the second order interaction (ch×k×d), were not significant for sucrose% in syrup, sucrose% in syrup, weight of syrup in all growth periods in the two seasons.

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Table (1) Physical and chemical properties of the experimental soil for the two 2009 and 2010 seasons.

Seasons	2009	2010
Mechanical analysis	Partial soil distribution:	
Sand %	37.9%	37.0%
Silt %	19.2%	20.0%
Clay %	42.9%	43.0%
Soil texture	clay loam soil	clay loam soil
Chemical analysis		
PH	8.16	8.17
EC (ds/m)	5.68	5.70
Mg++	3.70	3.66
Na+	5.00	5.06
Ca++	6.86	6.72
K+	0.38	0.33
Cl^-	2.79	2.73
$Co3^- + Hco3^-$	1.96	1.91
Available P (mg/kg soil)	3.12	3.00
Total nitrogen	0.15	0.12
Organic Matter %	1.37	1.28

Table (2): Mean values of leaf area index of *sweet sorghum* as influenced by chitocare (ch) treatments, potassium fertilization (k), plant density (d) and their interactions during 2009 and 2010 seasons.

Treatments	2009 Season Leaf area index Growth periods				2010 Season Leaf area index Growth periods			
	70days	90days	110days	At harvest	70days	90days	110days	At harvest
Chitocare treatments(ch)								
control	5.32b	5.77a	5.82c	6.33b	5.62b	5.72b	5.47b	6.02b
1spray	5.57b	5.84a	6.52b	7.24a	5.74a	5.92b	6.81a	6.19b
2sprays	5.98a	6.03a	7.11a	7.68a	5.87a	6.28a	6.94a	7.38a
K- fertilization(k)								
control	5.06b	5.51b	6.49b	6.60b	5.36b	5.41b	6.19b	6.26b
50kg/fad	6.19a	6.27a	6.71a	7.30a	6.17a	6.49a	7.00a	9.42a
Plant density (d)								
25cm	4.59c	4.80c	5.71c	5.77c	4.49c	5.84b	5.40c	5.52c
30cm	5.37b	5.94b	6.53b	6.85b	5.10b	7.04a	6.18b	6.55b
35cm	6.71a	7.15a	7.66a	8.13a	7.01a	7.05a	7.32a	7.83a
Interaction								
ch×k	NS	NS	NS	NS	NS	NS	NS	NS
ch×d	NS	NS	NS	NS	NS	NS	NS	NS
k×d	NS	NS	NS	NS	NS	NS	NS	NS
ch×k×d	NS	NS	NS	NS	NS	NS	NS	NS

N.S : Not significant

Means followed by the same letters within each columns are not significantly different according to L.S.D at 0.05 level of probability

Table (3): Mean values of Stalk yield of *sweet sorghum* as influenced by chitocare (ch) treatments, potassium fertilization (k), plant density (d) treatments and their interactions during 2009 and 2010 seasons.

Treatments	2009 Season Stalk yield (ton/fad)	2010 Season Stalk yield(ton/fad)
	Chitocare treatments(ch)	
control	13.12b	13.70b
1spray	13.19a	13.75b
2sprays	13.24a	13.85a
	K- fertilization(k)	
control	12.70a	11.67a
50kg/fad	12.99a	14.02a
	Plant density (d)	
25cm	12.61b	13.92b
30cm	12.69b	13.96b
35cm	12.91a	14.22a
	Interaction	
ch×k	NS	NS
ch×d	NS	NS
k×d	NS	NS
ch×k×d	NS	NS

N.S : Not significant

Means followed by the same letters within each columns are not significantly different according to L.S.D at 0.05 level of probability

Table (4): Mean values of weight of juice and 1000-grain weight of *sweet sorghum* as influenced by chitocare (ch) treatments, Potassium fertilization (k) , plant density (d)and their interactions during 2009 and 2010 seasons.

Treatments	2009 Season At harvest Growth period		2010 Season At harvest Growth periods	
	Weight of juice (ton/fad)	1000- grain weight (gm)	Weight of juice (ton/fad)	1000- grain weight (gm)
		Chitocare treatments(ch)		
control	2.15b	30.58c	2.05b	30.48c
1spray	2.30a	40.05b	2.20a	30.60b
2sprays	2.34a	40.70a	2.24a	30.95a
		K- fertilization(k)		
control	2.45a	30.73b	2.44a	30.63b
50kg/fad	1.99b	30.82a	1.89b	30.72a
		Plant density (d)		
25cm	2.16c	30.70a	2.06b	30.65a
30cm	2.26b	30.76a	2.06b	30.66a
35cm	2.37a	30.80a	2.17a	30.70a
		Interaction		
ch×k	NS	NS	NS	NS
ch×d	NS	NS	NS	NS
k×d	NS	NS	NS	NS
ch×k×d	NS	NS	NS	NS

N.S : Not significant

Means followed by the same letters within each columns are not significantly different according to L.S.D at 0.05 level of probability

Table (5): Mean values of total soluble solids in juice (T.S.S) of *sweet sorghum* as influenced by chitocare (ch) treatments, potassium fertilization (k), plant density (d) and their interactions during 2009 and 2010 seasons.

Treatments	2009 Season T.S.S (%) Growth period At harvest	2010 Season T.S.S (%) Growth period At harvest
	Chitocare treatments(ch)	
control	10.93c	10.22c
1spray	12.42b	11.05b
2sprays	13.43a	11.42a
	K- fertilization(k)	
control	11.26b	10.13b
50kg/fad	13.27a	12.13a
	Plant density (d)	
25cm	11.96c	10.91c
30cm	12.34b	11.15b
35cm	12.48a	11.33a
	Interaction	
ch×k	NS	NS
ch×d	NS	NS
k×d	**	**
ch×k×d	NS	NS

N.S : Not significant

Means followed by the same letters within each columns are not significantly different according to L.S.D at 0.05 level of probability

Table (6): The interactions between k fertilization and chitocare treatments on T.S.S of *sweet sorghum* during 2009 and 2010 seasons.

Chitocare treatments(ch)	K-fertilization(k)	2009 Season	2010 Season
		At harvest	At harvest
control	control	11.20	10.10
	50kg/fad	13.24	12.10
1spray	control	11.26	10.15
	50kg/fad	13.27	12.13
1spray	control	11.32	10.20
	50kg/fad	13.30	12.16
LSD $_{0.05}$		0.58	0.46

Table (7): Mean values of sucrose in syrup(%), sucrose in honey(%), weight of honey and weight of 100 seeds of *sweet sorghum* as influenced by chitocare (ch) treatments, potassium fertilization (k), plant density (d) and their interactions during 2009 and 2010 seasons.

Treatments	2009 Season At harvest			2010 Season At harvest		
	Sucrose in juice (%)	Sucrose in syrup (%)	Weight of syrup (kg)	Sucrose in juice(%)	Sucrose in syrup (%)	Weight of syrup (kg)
Chitocare treatments(ch)						
control	10.03b	16.37c	215.60b	9.94b	15.39c	243.60b
1spray	10.13b	17.52b	240.80a	10.01b	16.52b	266.00a
2sprays	11.41a	18.66a	249.20a	11.19a	17.66a	2.77.2a
K- fertilization(k)						
control	11.06a	18.10a	224.00b	10.85a	17.10a	249.20b
50kg/fad	10.65a	16.94b	246.40a	9.91b	15.95b	274.40b
Plant density (d)						
25cm	9.74a	16.51a	224.00a	9.20a	15.51a	252.00a
30cm	10.00a	17.86a	235.20a	10.08a	16.86a	263.20a
35cm	11.82a	18.19a	243.60a	11.86a	17.20a	271.60a
Interaction						
ch×k	NS	NS	NS	NS	NS	NS
ch×d	NS	NS	NS	NS	NS	NS
k×d	NS	NS	NS	NS	NS	NS
ch×k×d	NS	NS	NS	NS	NS	NS

N.S : Not significant

Means followed by the same letters within each columns are not significantly different according to L.S.D at 0.05 level of probability

الملخص العربى

تأثير الكثافة النباتية والتسميد البوتاسى والرش ببعض العناصر المغذية الصغرى على محصول وجودة الذرة السكرية

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أقيمت تجربتان حقليتان بمحطة البحوث الزراعية (بالصبحية) بالاسكندرية خلال موسمي الزراعة2009،2010 لدراسة تأثير تأثير الكثافة النباتية والتسميد البوتاسى و الرش بمغذى على المحصول والجودة فى الذرة السكرية وقد استخدم في التجربة تصميم القطع المنشقة مرتين في ثلاث مكررات حيث تم توزيع الرش بمغذى (بدون رش, رشة واحدة, رشتان) بالقطع الرئيسية ومعاملات السماد البوتاسى (صفركيلو جرام / للفدان،50كيلو جرام / للفدان) في القطع الشقية الأولى و مسافات الزراعة (25 ، 35,30 سم) بالقطع الشقية الثانية . وكانت أهم النتائج التالية:-

تفوقت معامله الرش بالمغذى (الشيتوكير) مرتان معنويا بكل من قيم لصفة دليل مساحة ألاوراق – محصول السيقان – وزن العصير والعسل ونسبة المواد الصلبة الذائبة الكلية عن المعاملة التى لم يتم فيها الرش بالمغذى .

أدى التسميد البوتاسى بمستوى 50كجم للفدان إلى إعطاء أعلى قيم لصفة دليل مساحة ألاوراق و نسبة المواد الصلبة الذائبة الكلية بينما أدى إلى تقليل محصولى العصير و العسل للذرة السكرية .

تفوق معنويا كل من قيم لصفة دليل مساحة ألاوراق – محصول السيقان – وزن العصير وزيادة نسبة المواد الصلبة الذائبة الكلية بالزراعة على مسافة 35 سم بين الجور وكانت غير معنوية بالزراعة على 25 سم بين الجور.

أعطى التداخل بين مستوى التسميد البوتاسى و الرش الورقى بالشيتوكير تأثير معنوى على نسبة المواد الصلبة الذائبة الكلية.