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Effect of Different Soil Types and Plant Densities on Growth Dynamic and Yield of Sweet Corn (*Zea mays* L.) in Peninsular Malaysia

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Authors' contributions

This work was carried out in collaboration among all authors. Author SSS designed the study, performed the statistical analysis, and wrote the first draft of the manuscript. Authors MFS, RI and SAR managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Soils and plant densities are two of the major factors affecting sweet corn growth and yield. Although many worldwide studies were done to evaluate the effect of these factors on sweet corn, it is still necessary to do more study in this area because environmental factors will give significant effect to growth and yield of sweet corn. The objective of this study is to assess yield optimization through different plant densities for different type of soils for sweet corn (*Zea mays* L.) cultivation.

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Study Design: The experiment was carried out from February to May 2018 using split-split plot design with four replications. Analysis of Variance (ANOVA) with probability value of @ 0.05 using LSD was used to analyze the obtained data. Regression analyses were performed using Nonlinear Regression Model (NLIN Procedure); Logistic Growth Model $y=A/(1+be^{-cx})$ and their rate of change was calculated using its derivate, $dy/dx = (Abce^{-cx})/(1+be^{-cx})^2$.

Methodology: A variety of sweet corn seed Akik SC422 at (i) four soils which were riverine soil (Tanah Merah, Kelantan), BRIS (Bachok, Kelantan), peat (Simpang Renggam, Johor) and sedentary soil (UPM, Serdang, Selangor) assigned as the main plots with (ii) 1 and 2 row(s) per bed plant arrangements as subplots at (iii) 25 cm and 50 cm planting distances formed as sub-subplots.

Results: Interaction between peat at 2-row per bed plant arrangement at 25 cm planting distance produced the highest potential plant height while peat at 1-row per bed plant arrangement at 50 cm planting distance the best in highest potential in stem diameter. The interaction between peat with 1-row per bed plant arrangement at 50 cm planting distance; low plant density produced the highest in cob weight, cob length, cob diameter, thousand kernel's weight and total sugar content. This was reflected by higher growth rates of photosynthesis rate, leaf area per plant and relative chlorophyll content of each individually plant. However, the interaction between peat with 2-row per bed plant arrangement at 25 cm planting distance; high plant density produced the highest in quantity per hectare.

Conclusion: Results of this study confirms that significant differences in the plant growth, physiological attributes and yield components of sweet corn grown on different soil types, plant arrangements and planting distances.

Keywords: Soil type; planting distance; plant arrangement; sweet corn.

1. INTRODUCTION

Soils in Peninsular Malaysia were developed from different parent materials, topography and geomorphology. Generally, they are divided into three major groups consisting of sedentary, alluvial, shallow organic, and miscellaneous soils that scattered all over Peninsular Malaysia (Fig. 1). Sedentary soils are soils developed in-situ over weathering parent materials or rocks and occur on undulating to steep terrains. This group of soils occupies major parts of Peninsular Malaysia, especially in areas along the main range [1]. Alluvial soils are also known as fluvial soils or alluvium. These soils are transported to their present position by rivers and streams. Alluvial soils occur extensively both along the east and west coast of Peninsular Malaysia [1]. About 26% of its total land surface in Peninsular Malaysia's area is comprised of peat [2]. The peat underlying tropical peat swamp forests accumulates because of the extreme conditions such as water-logged conditions, poor nutrient, anaerobic and acidic that impedes microbial activities [3].

The largest global producer of corn is the United States which constituted approximately 32% of the global production in 2012 [4]. In Africa, corn, the staple food for more than 24 million households, mainly planted in eastern and southern area of the continent with a total area of more than 15.5 million hectares [5]. Corn is the third most important food crop in Asia, after wheat and rice. This is mainly because of its adaptability to be grown throughout the year in most of the Asian countries [6]. Sweet corn production contributes significantly to most Asian economies due to its wider adaptability to be grown commercially under variety of climatic conditions with low investment [7]. In Malaysia, the production area for sweet corn and its yield was the highest in hectarage and production of cash crop, Malaysia by types in 2018 [1].

Farmers in Malaysia adopted different planting distances and plant arrangements in their agronomic practices for sweet corn cultivation. These cultural practices are based on planting manuals and their experiences. Differences in these cultural practices among farmers are most probably dependent on the soil dynamics due to nutrient in selected locations. Manuals on standard agronomic practices have been made available by Malaysian Agricultural Research Development Institute (MARDI) in 2005 and Department of Agriculture (DOA) in 2009 but the practices by farmers still vary from one location to another. One of the reasons given by farmers is the claim that the yield from their different practices is equivalent to the yield from the standard practice proposed by MARDI and DOA.

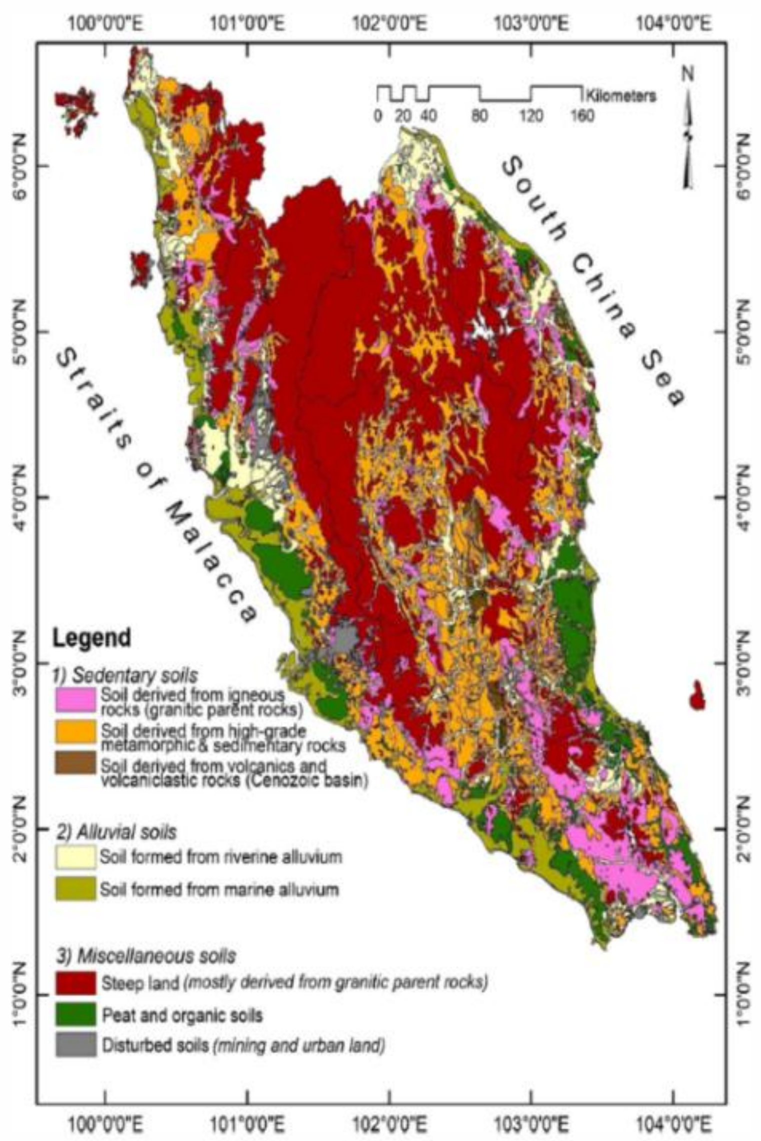

Fig. 1. Simplified distribution and classification of soils in Peninsular Malaysia
Source: Map of Soil types in Peninsular Malaysia, DOA, 2002

Numerous researches have been conducted at international level. However, there has been little info gathered thus far on the effects of different parameters on growth and development of sweet corn locally. The present study would be a significant contribution in providing quantitative proof of the effects of planting distances, plant arrangements and type of soils and on growth and yield of sweet corn at four locations using standard practices as control. The results of the study can be used by agriculture extension officers of relevant authorities in disseminating the appropriate information on the best practices for a specific location. The study may serve as a preliminary study on a minor scale targeted at a small segment of the overall population of farmers. Although, it may not be representative of the whole Malaysia scenario of agronomic practice, it surely provides an insight on a smaller scale on the impact of varying planting distances, plant arrangements and types of soils on growth and development of sweet corn in Peninsular Malaysia.

2. MATERIALS AND METHODS

2.1 Location and Study Duration

The study was carried out concurrently at four locations which were Tanah Merah (Riverine soil) and Bachok (BRIS), Kelantan, Simpang Renggam, Johor (Peat) and UPM, Serdang, Selangor (Sedentary soil). The experiment was started in February 2018 and ended in May 2018.

2.2 Experimental Design and Treatments

The three-factor experiment was conducted using split-split plot experimental design with the first factor was soil types consisted of four treatments which were riverine soil, BRIS soil, peat and sedentary soil assigned as the main plots. At each type of soil, the second factor; plant arrangements consisted of 2 treatments which were 1 and 2 row-per bed plant arrangements as subplots. The third factor; planting distances consisted of 2 treatments which were and 25 cm or 50 cm planting distances between plants formed as sub-subplots. Each plot was 50 m × 10 m and contained 4 rows; the size of the row was 1 m wide and distance between rows was 0.75 m of its respective plant arrangements and planting distances. The experiment carried four replications where each replication had 10 samples.

2.3 Planting Materials

Sweet corn seeds of variety Akik SC422 were sourced from Green World Genetics Sdn. Bhd. (GWG), a local seed supplier located at Batu Arang, Rawang, Selangor. The seeds were directly sown at the research plots set at different plant arrangements and planting distances in every study location. All plants received uniform cultural practices throughout the duration of the experiment.

2.4 Data Collection

2.4.1 Monthly mean air temperature and total monthly precipitation

Climate change parameters such as total amount of monthly precipitation (mm) and monthly mean air temperature (°C) were considered in this research. The monthly time series data for the parameters of climate change during the months from February to May 2018 was used due to the availability of data from Malaysian Meteorological Department (MET). Comparisons were made among four meteorological stations at Veterinary Office, Machang (5° 46' N, 102° 12' E) and Kota Bharu (6° 09' 49" N, 102° 18' 02" E) in Kelantan, Petaling Jaya, Selangor (3° 06' 07" N, 101° 38' 42" E) and Felda Bukit Batu, Johor (1° 42' N, 103° 26' E).

2.4.2 Soil analysis

Soil samples from each location were collected before the start of the experiment. Soil samples from each location was collected before and at the end of the experiment. They were then be analyzed to determine its physical and chemical properties. The analytical approach to determine mineral N concentration is potassium chloride extraction while for Organic N is using 'Kjeldahl N' method. Bray Method is used to extract Phosporus and Ammonium acetaten is used for Potassium extraction [8].

2.4.3 Growth of plant height and stem diameter

To explore the dynamics of plant growth and development, quantitative data on the change in plant height (cm) and stem diameter (cm) from every treatment at all locations were recorded on 2nd, 4th, 6th and 8th weeks after planting (WAP). For plant height, measurements were taken from the base of the plants to the tips of the tassel using a measuring tape. Stem diameter was measured at the first node of the stem plant using a pair of vernier caliper. Data for both parameters were recorded in centimeter and modelled using the Logistic Growth Model [9]. Data on plant height and stem diameter were non-linearly regressed against WAP by using the equation $y=A/(1+be^{-cx})$, where y=growth parameter; plant height or stem diameter, A=potential plant height or stem diameter, b=constant as time scale parameter, c=growth rate, x=time and e=error or residual. This model is symmetric between its asymptotes; the lower asymptote is equal to 0 and the upper asymptote is y=A; when x=0 we get y=A(1+b) as an initiation. In addition, the derivative of the above growth function $[dy/dx =(Abce^{-cx})/1+be^{-cx})^2]$, where y, x, A, b and c were used in estimating the growth rate (cm/week) of each parameter. Cob weight per plant, cob length, number of rows per cob, number of kernels per row and total sugar content were observed and recorded on harvest day. The average cob weight per plant was converted to per hectare basis. Data from all the observations were analyzed using Analysis of Variance (ANOVA) of Statistical Analysis System (SAS) Program version 9.4. The differences among treatments were tested using Least Significant Difference (LSD) at *P*= 0.05 probability level.

2.4.4 Physiological attributes of photosynthesis rate, leaf area index and relative chlorophyll content

Photosynthetic rate was measured on the 8th leaf from base of the plants at 8th WAP using a portable infrared gas analyzer (CIRAS 3, PP System, Hansatech, UK). Leaf area was measured by harvesting plants and measuring of individual leaves using LI-COR LI-300A leaf area meter. Leaf area measurements were taken at 67 DAP on the harvesting days. Relative chlorophyll content (%) of the plants was recorded at 8th WAP using hand-held chlorophyll meter Minolta SPAD-502s. Four replicate measurements of samples were measured from 10:00 a.m. to 12:00 p.m. Measurement conditions were kept consistent: LED light source, and the PAR was 1500 μmol m^{-2}. Carbon dioxide (CO_2) concentration was maintained at a constant level of 390 μmol mol^{-1} using a CO_2 injector with a high-pressure liquid CO_2 cartridge source.

2.4.5 Yield components

Every parameter in yield components was observed and recorded on harvesting day at 67 DAP. The weight of cob per plant, recorded in gram (g), using an electronic balance and then converted into per hectare for total weight per hectare (kg/ha). The length of cob (cm) was measured between base and apex using a pair of vernier caliper. The number of rows per cob was counted at base region of each cob. The number of kernels per row was measured between the base and apex of each cob. Measurement of total sugar content (%) was performed to measure total sugar content in harvested aqueous solution extracted from the kernel kernel's cob from each treatment using a refractometer.

2.4.6 Statistical analysis

Data from all observations were analyzed using Analysis of Variance (ANOVA) of Statistical Analysis System (SAS) Program version 9.4. Regression analyses were performed using Nonlinear Regression Model (NLIN Procedure); Logistic Growth Model of $y=A/(1+be^{-cx})$ and their rate of change was calculated using its derivate, $dy/dx=(Abce^{-cx})/(1+be^{-cx})^2$. The differences among treatments were tested using Least Significant Difference (LSD) at *P*= 0.05 probability level.

3. RESULTS AND DISCUSSION

3.1 Mean Air Temperature of Experimental Sites

An overview of mean air temperature for the four study locations is presented in Table 1. Among the four locations, UPM, Serdang, Selangor had the highest mean air temperature during the five months of the year (34.0°C for April 2018). The lowest mean air temperature was recorded at Simpang Renggam, Johor in January (30.3°C). This suggests that all locations received the optimum range of temperatures (30°C to 35°C) for growth of sweet corn [10].

3.2 Monthly Precipitation of Experimental Sites

An overview of monthly precipitation distribution of the four study locations as a whole is presented in Table 1. From February to June 2018, UPM, Serdang, Selangor had the highest total rainfall among the 4 study locations with the highest been 598.4 mm in May 2018 which was due to South West Monsoon (SWM) that occurred from May to September. In January 2018, Bachok, Kelantan received the highest total rainfall (297.0 mm) due to North East Monsoon (NEM) which occurred from November to March (Table 1). Even though the amount of rainfall at all four locations varied and had a high range, it was not the reason which affected yield of sweet corn considering that farmers at every location used irrigation system and did not depend on the amount of rain received [11]. Sweet corn required a minimum of 600-900 mm for 1 season cycle through irrigation or rainfall [10].

3.3 Physico-chemical Properties of Experimental Soils

The general physical and chemical properties of the four types of soils used in the experiment are presented in Table 2. All soil types were recorded to be very strongly acidic with pH ranging from 4.08 in sedentary soil to 5.17 in peat. Soil organic carbon was lowest (0.96 g/kg) in sedentary soil and highest (29 g/kg) in peat. Peat had very high organic matter (76.02 g/kg), while BRIS had extremely low organic matter (2.86 g/kg). Total nitrogen was considered as very high in peat (2.30 g/kg) while in riverine soil, total nitrogen was considered as low (0.09 g/kg). CEC in peat classified as very high (84.75 cmol (+)/kg) while BRIS classified as very low (2.2 cmol (+)/kg) [12].

Table 1. Weather data of experimental locations during sweet corn growing season

2018	Mean air temperature (°C)				Total rainfall (mm)			
	B	TM	UPM	SR	B	TM	UPM	SR
January	30.8	30.1	31.0	30.3	297.0	68.1	230.6	124.1
February	31.3	30.6	33.6	31.4	99.0	89.3	289.0	43.1
Mac	32.3	31.1	33.6	32.0	43.6	53.2	486.8	238.1
April	32.8	32.3	34.0	32.1	84.8	40.2	314.0	323.1
May	33.9	32.9	33.4	32.0	42.8	61.5	598.4	370.6
June	33.4	32.4	33.9	32.0	140.4	137.0	264.6	184.1

B: Bachok, Kelantan, TM: Tanah Merah, Kelantan, UPM: UPM Serdang, Selangor and SR: Simpang Renggam, Johor. Total rainfall is monthly sums, while air temperature is monthly mean in sweet corn growing season (Source: MET Malaysia, 2019.)

Table 2. Physico-chemical properties of experimental sites particle size distribution

	Bachok (BRIS)	Tanah merah (Riverine)	Serdang (Sedentary)	Simpang renggam (Peat)
Physical characteristics				
Sand (%)	87.87	16.22	45.93	11.61
Silt (%)	6.07	56.17	16.60	36.58
Clay (%)	6.06	27.60	37.47	51.78
Soil texture	Sand to loamy sand	Silty clay loam	-	Sandy clay
Chemical characteristics				
pH (H_2O)	4.80	4.63	4.08	5.17
Organic carbon (g/kg)	1.66	0.16	0.96	29.00
Organic matter (g/kg)	2.86	7.95	6.25	76.02
Total nitrogen (g/kg)	0.11	0.09	0.14	2.30
Available P (g/kg)	7.40	-	-	-
Ex. Ca (cmol (+)/kg)	0.04	0.09	0.07	0.83
Ex. Mg (cmol (+)/kg)	0.01	0.02	0.22	1.09
Ex. K (cmol (+)/kg)	0.04	0.19	0.26	0.13
Ex. Na (cmol (+)/kg)	0.02	0.07	0.04	0.35
CEC (cmol (+)/kg)	2.20	5.00	5.80	84.75
Exc. acidity				
Al	4.50	1.21	2.04	9.64
EC (dS/m)	328	445	387	28760

3.4 Growth of Plant Height and Stem Diameter

Changes in plant height and stem diameter of the sweet corn were monitored at every 2 weeks beginning from the second Week After Planting (WAP). The performance of sweet corn from different plant arrangements and planting distances for each type of soils indicate that plant height (Fig. 2) and stem diameter (Fig. 3) increased continuously over time. Both growth of plant height and stem diameter achieved their maximum then remained constant till the plant reached physiological maturity.

The pattern of growth bears a strong resemblance to a sigmoid curve in which the plant height and stem diameter increased rapidly then continued to be plateau. Table 3 and Table 4 show that constants were well-fitted into the growth function of $y= A/(1+be^{-cx})$. The R^2 stated were ranged 0.94 to 0.99 respectively, meaning that the variance of plant height and stem diameter were about 94% to 99% as explained by the Logistic Model. This strongly indicates that the model is best to describe the growth of sweet corn.

Using Logistic Model function; symmetric between asymptotes when y=A; when x=0, y=A/(1+b) as a potential plant growth, results stated on Table 3 shows that the highest potential plant height was achieved on peat with 2-rows per bed plant arrangement at 25 cm planting distance; high plant density at y=A=249.9 cm ($y=249.9/(1+179.1e^{-0.811x})$) and the least in potential plant height was achieved on sedentary soil with 1-row per bed plant arrangement at 50 cm planting distance; low plant density at y=A=161.2 cm ($y=161.2/(1+148.3e^{-01.552x}$). Correspondingly, Table 4 shows 1-row per bed plant arrangement at 50 cm planting distance; low plant density on peat produced the highest potential in stem diameter at y=A=4.08 cm ($y=4.08/(1+0.86e^{-1.20x}$), and the lowest potential was on sedentary soil with 2-row per bed plant arrangement at 25 cm planting distance at y=A=2.90 cm ($y=2.90/(1+0.67e^{-1.27x}$).

Stem diameter generally increase with the increase in planting distance from 25 cm to 50 cm but the magnitude of the increase is bigger in 1-row plant arrangement especially in peat and riverine soil. These results were due to competition for nutrients and space between the sweet corn plants. The results are in good agreement with the findings of [13,14,15]. The effects were reversed in plant height; decrease in planting distance and addition of 2-row plant arrangement increased the plant height indicating that competition between plants for sunlight increases with increasing plants per unit area. The results were in line with [16,17,18].

Table 5 shows that growth rate for plant height and stem diameter are estimated using a function $dy/dx=(abce^{-cx})/(1+be^{-cx})^2$. The maximum growth rate of plant height occurred at 6th WAP in the range of 46.6 cm/week at 1-row per bed plant arrangement at 50 cm planting distance on sedentary soil to 62.7 cm/week at 2-row per bed plant arrangement at 25 cm planting distance on peat (Fig. 4). However, highest growth rate for stem diameter occurred at 4th WAP in the range of 0.72 cm/week on sedentary at 2-row per bed plant arrangement at 25 cm planting distance to 1.26 cm/week on peat at 1-row per bed plant arrangement at 50 cm planting distance (Fig. 5). Plant growth decreases at faster rate till maturity after it achieved the maximum growth rate. The decreases are due to cessation of vegetative growth, loss of leaves, and senescence [19].

3.5 Physiological Attributes of Photosynthesis Rate, Leaf Area Index Leaf Area Per Plant, and Relative Chlorophyll Content

Leaf Area Index (LAI) increased with increasing plant density. Fig. 6 shows that at 67 DAP, LAI on peat with 2-row per bed plant arrangement at 25 cm planting distance; high plant density produced the highest in LAI at 11.215 while LAI on sedentary soil with 1-row per bed plant arrangement at 50 cm planting distance; low plant density was the least at 3.497. On the contrary, leaf area per plant decreased with greater plant density. Fig. 7 shows that at 67 DAP, leaf area per plant on peat with 1-row per bed plant arrangement at 50 cm planting distance; low plant density reported the best leaf area per plant at 1.451 m^2 compared to sedentary soil with 2-row per bed plant arrangement at 25 cm planting distance; high plant density stated the lowest leaf area per plant at 0.908 m^2. This suggests that different plant arrangements and planting distances; plant densities influenced leaf size in an attempt to maximize the overall resources needed for growth and development of sweet corn. The significance of LAI comes from the importance of leaves as a source of carbohydrates produced during photosynthesis, which are converted to myriad of chemicals that the plant needs. These results are in-line with Sharifi and Namwar [20] reported that LAI was greater under 11 plants/m^2 at 2.53 than dense plants under 7 plants/m^2 at 2.38. Low LAI was obtained at higher plant density as a consequence of interplant competition [21].

Relative chlorophyll content of plant leaves was significantly affected by plant density. Fig. 8 shows that the highest relative chlorophyll content at 58.90% in plant was achieved on peat with 1-row per bed plant arrangement at 50 cm planting distance; low plant density. Contrarily, the least relative chlorophyll content at 48.61% in plant was obtained on sedentary soil with 2-row per bed plant arrangement at 25 cm planting distance; high plant density. Relative chlorophyll content catalyses the reaction involving photosynthesis involving the conversion of CO_2 and H_2O into carbohydrate in presence of light. The result of this study is consistent with Salifu [22] who stated that the percentage of relative chlorophyll content in corn was recorded with higher values for low plant density on 60,000 plants/ha (64.91%) as compared to 72,500 plants/ha (58.27%) and 75,000 plants/ha (53.42%).

Photosynthesis rate decreased significantly with increasing plant density. Fig. 9 shows that at 8th WAP, the photosynthesis rate on peat with 1-row per bed plant arrangement at 50 cm planting distance; low plant density gave the highest result at 46.93 $\mu molCO_2m^{-2}s^{-1}$. However, sedentary soil with 2-row per bed plant arrangement at 25 cm planting distance gave the lowest result at 30.033 $\mu molCO_2m^{-2}s^{-1}$. Plant use photosynthesis to produce carbohydrates from inorganic substrates and play important roles for building the structure of plant cells. Similar study conducted by Ren B, Liu W, Zhang J, Dong S, Liu P, Zhao B [23] at plant densities of 45,000, 60,000, 90,000 and 120,000 plants/ha, photosynthesis rate decreased by 14, 17, 24 and 30 µmol$CO_2m^{-2}s^{-1}$ respectively.

Table 3. Constants of plant height of sweet corn at four types of soils using a function $y = A/(1+be^{-cx})$

Treatments	Constants			F-value	Approx. Pr>F	Approx. R^2
	A	b	c			
Pe:DR:25	249.9	179.1	0.81	305.11	0.04	0.99
Pe:SR:25	248.3	115.7	0.90	922.5	0.02	0.99
Pe:DR:50	212.2	270.8	1.07	305.1	0.01	0.99
Pe:SR:50	165.5	124.8	1.54	278.5	0.02	0.99
B:DR:25	246.2	173.2	0.80	253.2	0.04	0.99
B:SR:25	240.5	106.9	0.84	297.4	0.02	0.99
B:DR:50	200.2	211.8	0.99	716.0	0.03	0.99
B:SR:50	175.1	327.0	1.24	454.4	0.01	0.99
R:DR:25	237.7	186.6	0.33	428.0	0.02	0.99
R:SR:25	225.4	119.8	0.87	332.7	0.01	0.99
R:DR:50	215.8	127.6	0.32	579.0	0.02	0.99
R:SR:50	211.2	156.2	0.94	327.2	0.02	0.99
S:DR:25	187.2	128.3	1.52	762.5	0.03	0.99
S:SR:25	174.2	110.3	1.48	826.3	0.03	0.99
S:DR:50	174.2	124.3	1.53	690.9	0.03	0.99
S:SR:50	161.2	148.3	1.552	368.2	0.02	0.99

Y: Plant height, A: Potential plant height, b: Constant, c: Growth rate, x: Time, e: Error. Pe: Peat, B: BRIS Soils, R: Riverine Soils, S: Sedentary soils. SR: Single row of plant arrangement, DR: Double row of plant arrangement, 25: 25 cm planting distances, 50: 50 cm planting distances

Table 4. Constants of stem diameter of sweet corn at four types of soils using a function $y = A/(1+be^{-cx})$

Treatments	Constants			F-value	Approx. Pr>F	Approx. R^2
	A	b	c			
Pe:DR:25	3.15	0.36	2.09	1211.33	0.02	0.94
Pe:SR:25	3.60	0.37	0.99	351.97	0.04	0.97
Pe:DR:50	4.02	0.02	1.61	688.61	0.03	0.97
Pe:SR:50	4.08	0.86	1.20	7325.85	0.01	0.97
B:DR:25	3.15	0.01	1.40	1333.18	0.02	0.96
B:SR:25	3.21	0.94	1.28	118444	0.01	0.97
B:DR:50	3.32	0.01	1.32	1004.07	0.02	0.97
B:SR:50	4.04	0.44	0.99	44.29	0.11	0.96
R:DR:25	3.01	0.03	1.64	35.78	0.12	0.97
R:SR:25	3.58	0.02	1.80	24239.5	0.01	0.97
R:DR:50	3.60	0.65	1.16	589.85	0.03	0.96
R:SR:50	3.80	0.01	1.33	166.6	0.05	0.98
S:DR:25	2.90	0.67	1.27	198.68	0.04	0.95
S:SR:25	3.55	0.01	1.30	484.16	0.03	0.98
S:DR:50	3.56	0.02	1.51	889.69	0.02	0.96
S:SR:50	3.68	0.89	1.22	256.1	0.01	0.96

Y: Plant height, A: Potential plant height, b: Constant, c: Growth rate, x: Time, e: Error. Pe: Peat soils, B: BRIS soils, R: Riverine soils, S: Sedentary soils. SR: Single row of plant arrangement, DR: Double row of plant, arrangement, 25: 25 cm planting distances, 50: 50 cm planting distances

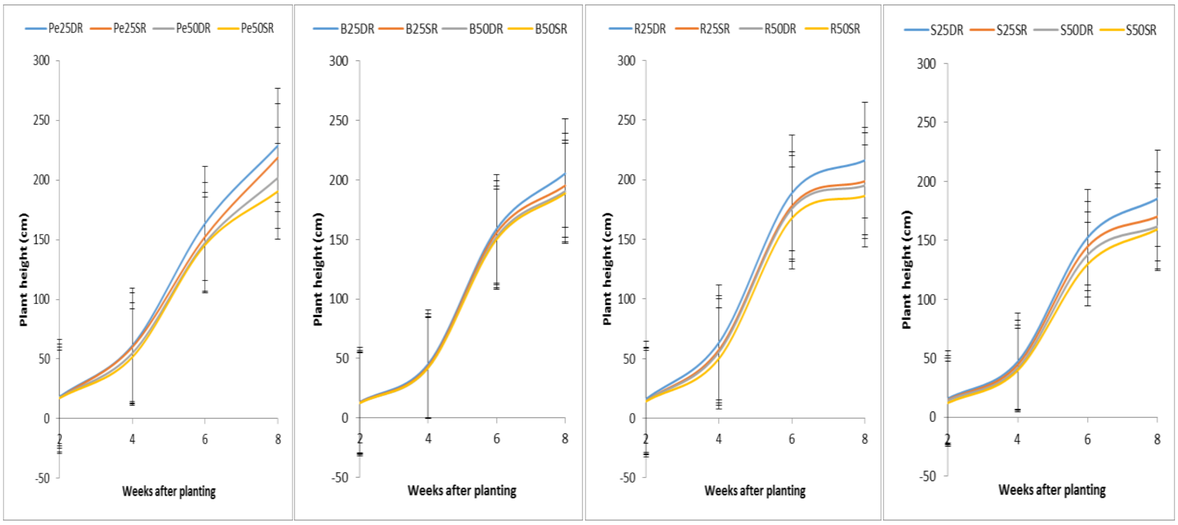

Fig. 2. Plant height in the form of y=A/(1+be^{-cx}) of sweet corn during 8 weeks of growing duration

Pe: Peat, B: BRIS, R: Riverine, S: Sedentary, SR: Single row of plant arrangement, DR: Double row of plant arrangement, 25: 25 cm planting distance, 50: 50 cm planting distance

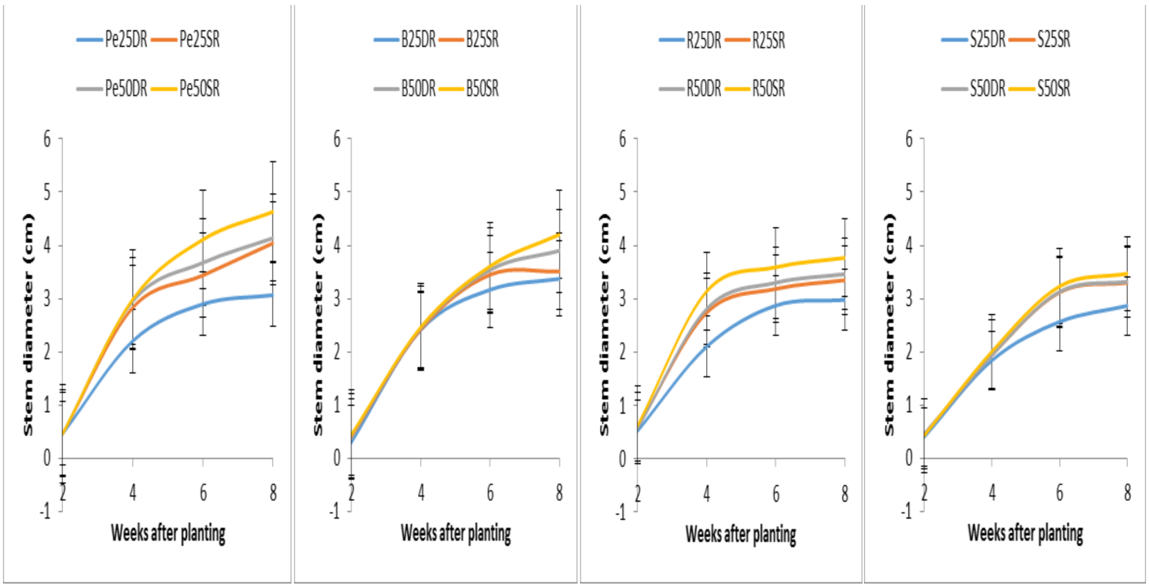

Fig. 3. Stem diameter in the form of y=A/(1+be^{-cx}) of sweet corn during 8 weeks of growing duration

Pe; Peat, B; BRIS, R; Riverine, S; Sedentary, SR; Single row of plant arrangement, DR; Double row of plant arrangement, 25; 25 cm planting distance, 50; 50 cm planting distance

At higher plant density, leaf area per plant is decreased. Similar finding in relative chlorophyll content, results show that relative chlorophyll content is decreased at higher plant density. Decline in both leaf area and relative chlorophyll content per plant led to the decrease of photosynthetic activities in the decline of net photosynthesis rate and reduced final yield; cob weight, cob length, cob diameter, number of row per cob, number of kernel per row, 1000 kernel's weight and total sugar content produced per plant as plant population increased. The findings in this study coincide with those of Antonietta M, Fanello DD, Acciaresi HA, Guiamet JJ [24] who stated that higher plant density of maize increases the vegetative growth resulting in a higher number of leaves and more intense leaf extension per plant which leads plant to facilitate photosynthetic activities; reduced net photosynthesis which cause detrimental to final yield.

3.6 Yield Components

Table 6 shows that interaction between soil types, plant arrangements and planting distances gave significant difference for all yield components. The interaction between peat with 1-row plant arrangement at 50 cm planting distance produced the highest cob weight at 586.9 g. Meanwhile, the lowest significant interaction for cob weight was at sedentary soil with 2-row per bed plant arrangement at 25 cm planting distance at 422.5 g. For cob length, the highest interaction effect was at peat with 1-row per bed plant arrangement at 50 cm planting distance at 20.97 cm while the least interaction was at sedentary soil at 2-row per bed plant arrangement at 25 cm planting distance at 17.78 cm. Peat with 1-row per bed plant arrangement at 50 cm planting distance produced the highest in cob diameter at 5.66 cm. However, sedentary soil at 1-row per bed plant arrangement at 25 cm planting distance produced the lowest at 3.65 cm. The study indicated that the highest number of row per cob (17.58) was produced at sedentary soil with 2-row per bed plant arrangement at 25 cm planting distance and the least number of row per cob (15.23) was produced at peat with 2-row per bed plant arrangement at 25 cm planting distance. Number of kernel per row reported the highest (41.23) at BRIS with 2-row per bed plant arrangement at 25 cm planting distance and the lowest (36.53) was reported at sedentary soil with 1-row per bed plant arrangement at 25 cm planting distance. The study showed that peat with 1 and 2-row per bed plant arrangement at 50 cm planting distance produced the highest thousand kernel's weight (459.86 g and 442.24 g). Meanwhile, the lowest result for thousand kernel's weight produced at BRIS with 2-row per bed plant arrangement (348.27 g), riverine soil with 1-row per bed plant arrangement at 25 cm (352.05 g), riverine soil with 2-row per bed plant arrangement at 50 cm planting distance (346.95 g) and sedentary soil with 1 row per bed plant arrangement at 25 cm planting distance (360.54 g). The interaction between peat with 1-row per bed plant arrangement at 50 cm planting distance gave the highest result for total sugar content at 16.25%. However, interaction between riverine soil with 1-row per bed plant arrangement at 25 cm planting distance gave the least for total sugar content at 14.22%.

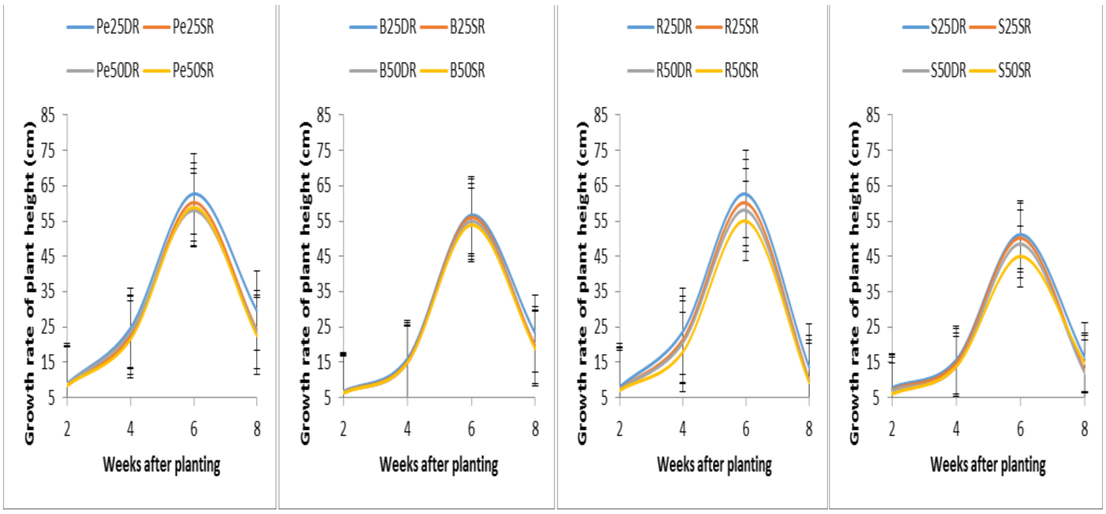

Fig. 4. Growth rate of plant height in the form of dy/dx = $(Abce^{-cx})/(1+be^{-cx})^2$ of sweet corn during 8 weeks of growing duration

Pe; Peat, B; BRIS, R; Riverine, S; Sedentary, SR; Single row of plant arrangement, DR; Double row of plant arrangement, 25; 25 cm planting distance, 50; 50 cm planting distance

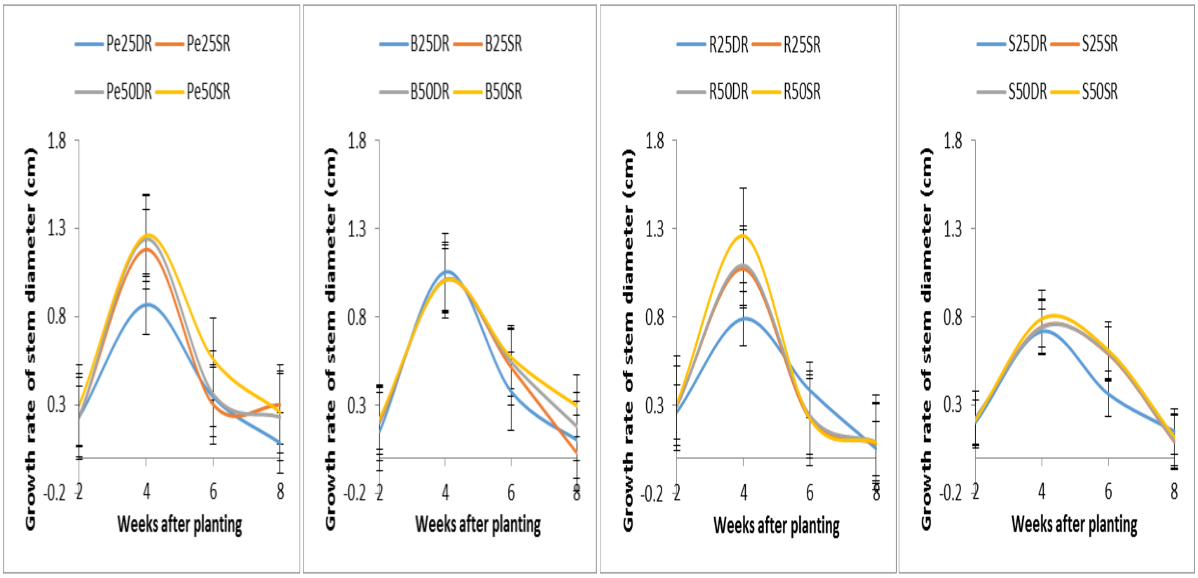

Fig. 5. Growth rate of stem diameter in the form of dy/dx = $(Abce^{-cx})/(1+be^{-cx})^2$ of sweet corn during 8 weeks of growing duration

Pe; Peat, B; BRIS, R; Riverine, S; Sedentary, SR; Single row of plant arrangement, DR; Double row of plant arrangement, 25; 25 cm planting distance, 50; 50 cm planting distance

Table 5. Growth rates of plant height and stem diameter of sweet corn at four types of soils during 8 weeks growing duration estimated using a function dy/dx =$(abce^{-cx})/(1+be^{-cx})^2$

Treatments	Week after planting	Plant height (cm/week)	Stem diameter (cm/week)
Pe:DR:25	2	9.00	0.23
	4	24.67	0.87
	6	62.70	0.35
	8	29.55	0.08
Pe:SR:25	2	8.50	0.23
	4	22.50	1.18
	6	60.25	0.30
	8	24.17	0.30
Pe:DR:50	2	8.83	0.23
	4	23.50	1.24
	6	60.05	0.36
	8	23.66	0.23
Pe:SR:50	2	8.50	0.30
	4	21.50	1.26
	6	58.85	0.56
	8	22.50	0.26
B:DR:25	2	6.74	0.15
	4	15.99	1.06
	6	56.69	0.38
	8	23.33	0.10
B:SR:25	2	6.55	0.20
	4	15.23	1.01
	6	56.06	0.52
	8	19.72	0.03
B:DR:50	2	6.50	0.21
	4	14.75	1.01
	6	54.96	0.55
	8	18.94	0.18

Treatments	Week after planting	Plant height (cm/week)	Stem diameter (cm/week)
B:SR:50	2	6.30	0.23
	4	14.89	1.00
	6	53.87	0.57
	8	18.87	0.30
R:DR:25	2	8.05	0.26
	4	23.70	0.79
	6	62.65	0.25
	8	13.70	0.05
R:SR:25	2	7.30	0.30
	4	21.50	1.07
	6	60.15	0.22
	8	10.3	0.08
R:DR:50	2	7.25	0.30
	4	20.56	1.09
	6	58.05	0.24
	8	9.70	0.09
R:SR:50	2	7.10	0.31
	4	17.95	1.26
	6	55.02	0.23
	8	9.32	0.09
S:DR:25	2	7.85	0.20
	4	15.70	0.72
	6	51.17	0.36
	8	16.47	0.15
S:SR:25	2	7.30	0.23
	4	14.95	0.75
	6	50.00	0.59
	8	12.70	0.09
S:DR:50	2	7.05	0.23
	4	13.80	0.74
	6	48.50	0.60
	8	11.98	0.10
S:SR:50	2	6.05	0.22
	4	13.82	0.79
	6	46.66	0.61
	8	9.82	0.12

Pe: Peat, B: BRIS soils, R: Riverine soils, S: Sedentary soils, SR: Single Row of plant arrangement, DR: Double row of plant arrangement, 25: 25 cm planting distances, 50: 50 cm planting distances

Table 7 shows that interaction between peat with 2-row per bed plant arrangement at 25 cm planting distance; 106,600 plants per hectare produced the highest cob weight per hectare at 53,426 kg/ha. However, the same treatment produced among the lowest result for cob weight per plant (0.492 kg/plant). Meanwhile, the interaction between peat with 1-row per bed plant arrangement at 50 cm planting distance; 26,650 plants per hectare produced the lowest cob weight per hectare at 15,641kg/ha. However, the similar treatment gave the highest result for cob weight per plant (0.590 kg/plant).

Soil types, plant arrangement and planting distance individually gave significant effect on growth and yield components of sweet corn. The result from this study shows that the highest cob weight per hectare of sweet corn was produced at 2-row per bed plant arrangement at 25 cm planting distance; high plant density in peat. This was due to the presence of a greater number of plants per unit area which represented higher leaf area index yet negatively influenced the production of each individual cob produced for each plant. The highest cob weight per hectare in peat was obtained at 2-row per bed plant arrangement at 25 cm planting distance (52,426 kg/ha) which increased 184% compared to conventional 1-row per bed plant arrangement at 25 cm planting distance (28,356 kg/ha) in sweet corn. This fact was also observed and confirmed by Paththinige SS et al, Cavalaris C et al, Verma B et al. [25,26,27] which reported that higher yield per hectare were found at closer planting distance could be attributed to the significant higher plant density achieved. However, the highest cob weight per plant of sweet corn was obtained at plants raised by 1-row per bed plant arrangement and 50 cm; low plant density compared to plants raised by 2-row per bed plant arrangement and 25 cm planting distance; high plant density. High plant density gave unbalanced plant growth with insufficient availability of growth factors that could enhance the competition among plant, so their growth declines. Increase in plant density causes the assimilate proportion for every kernel of the cob decline, so that the kernel size become small and results in lowest of thousand kernel's weight per plant. According to Mahmood S [28], the best quantity of yield per plant was produced by the plants at the wider distance (50 ×5 cm) compared to narrow distance (50×10 cm and 50×15 cm). Gulluoglu L, Halil Bakal H, Arioglu H [29] in their experiment found that higher yield per plant were produced at wider distance at 70×25 cm as compared to closer distance at 75×25 cm and 80×25 cm. Furthermore, Johu PHS, Sugito Y, Guritno B [30] reported that high plant density could make more plants be barren that reduces the plant production.

Soil types individually gave significant effect on growth and yield components of sweet corn. Peat was superior to all other soils types and consistently produced significant higher values over other soil types for cob weight, cob diameter, 1000 kernel weight, number of row per cob and number of kernel per row. Every soil type is different in its properties which ultimately result in differences in drainage, texture, fertility and pH. This has led to significant impact on growth and yield of sweet corn. Soil fertility differs significantly in amount and combination of nutrients. Peat contains with high organic matter, organic carbon, total nitrogen and high cation exchange capacity (CEC) that improved soil fertility status which resulted in an improved yield of sweet corn compared to riverine, BRIS and sedentary soil. A similar study by Minardi S et al, Masanobu O et al. [31,32] that plants grew faster and healthier with larger stem diameter and longer internode in gray soil than in dark red soil and red soil. Peat possesses the highest percentage of clay among the other type of soils and have high surface area in holding plant nutrients which contribute to the high amount of chemical and physical activity. Furthermore, diversity in physical properties of soils determines the capability of soils to hold nutrients that finally contribute to the development of plants and its yield. The result of this experiment is also in tandem with the research findings of McKenzie NJ et al, Abdul Khalil HPS et al. [33,34] whose report indicates that higher amount of clay in peat tended to increase quality plant yield. Report of this study is in-line with the study conducted by Jawayria AR et al. [35] where the physical edaphic factors in soils most likely responsible for growth and biomass productivity.

Plant arrangement and planting distance are two of the essential factors that affect plant density which significantly effect on growth and yield components of sweet corn. Plant arrangement is defined as the pattern of plants over the ground by changing row spacing and planting seeds individually or in groups which determine the shape of the area available to the individual plant. Meanwhile, planting distance is the distance between one plant to another in a given row. These factors play important roles and significantly influence the sweet corn yield components.

Plant arrangement individually gave significant effect on yield components of sweet corn. Two-row per bed plant arrangement resulted in more aborted plants and decrease in cob weight. Two-row per bed plant arrangement gave the lowest significant in cob length. At 2-row per bed plant arrangement, number of kernels produced the least result. Thousand kernel's weight decreased with increasing number of plant arrangement at 2-row per bed plant arrangement. At 2-row per bed plant arrangement, increased competition for growth factors would be expected, and yield components per plant were indeed lower due to the excessive number of plants. The reduction in yield components in 2-row per bed plant arrangement; higher densities enhance intra-competition, decrease the growth of single-plant crops and decelerate the development of kernels due to limited nutrient supply to the cob. Numbers of plant arrangement can affect appropriate plant density and increase resource competition relationships which are crucial in crop productivity. Gozubenli H et al. [36] observed that cob length, cob diameter and kernel weight per plant decreased with increasing of number of row per bed plant arrangement. Greveniotis V, Zotis S, Sioki S, Ipsilandis C [37] also in-line with the finding, they stated that yield components were favored by low density at 1-row plant arrangement compared to 2-rows per bed plant arrangement. Finding of Akbar MA [38] reported that number of kernels per row, kernel per cob, 1000 kernel weight and cob weight planted in 2-row per bed plant arrangement produced significantly lower compared to 1-row per bed plant arrangement. They reported that plants grown under high competition has lower potential yield components than those under sparse plantings. It affected competition among plants for space, water and nutrient used which detrimental to final yield.

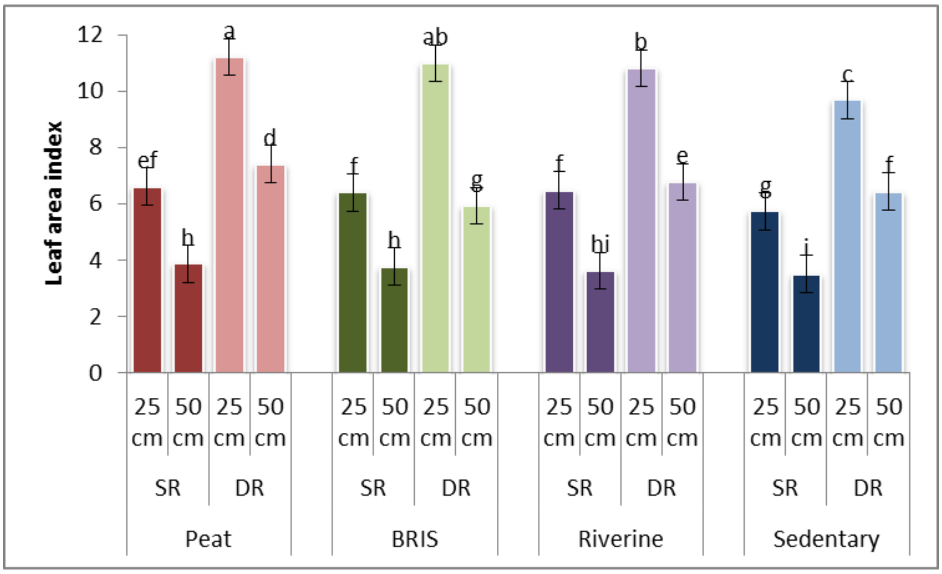

Fig. 6. Leaf area index taken at 67 DAP on the harvesting days planted on different type of soils, plant arrangements (SR; Single row of plant arrangement, DR; Double row of plant arrangement) and planting distances

Means with different letters is significantly different at P= 0.05 using LSD

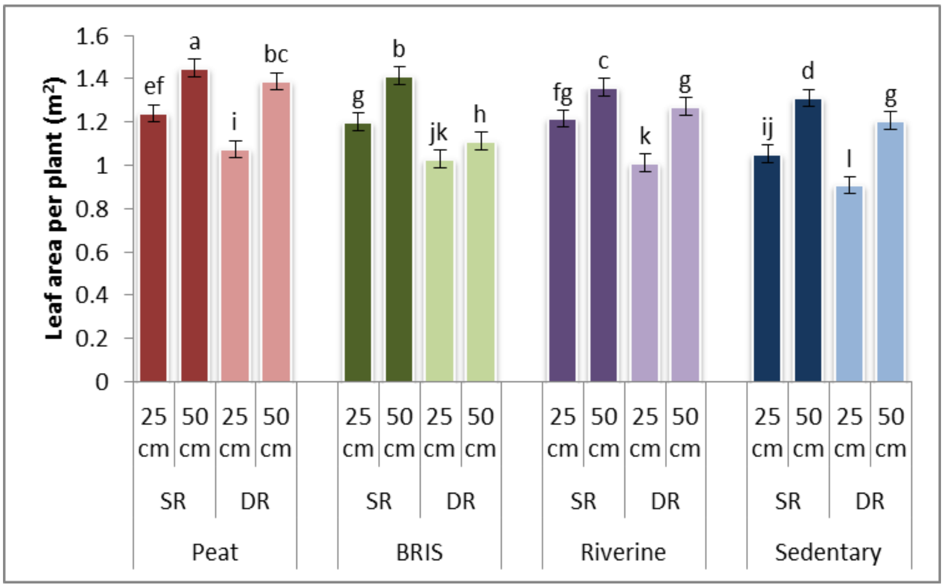

Fig. 7. Leaf area per plant taken at 67 DAP on the harvesting days planted on different type of soils, plant arrangements SR; Single row of plant arrangement, DR; Double row of plant arrangement) and planting distances.

Means with different letters is significantly different at P= 0.05 using LSD

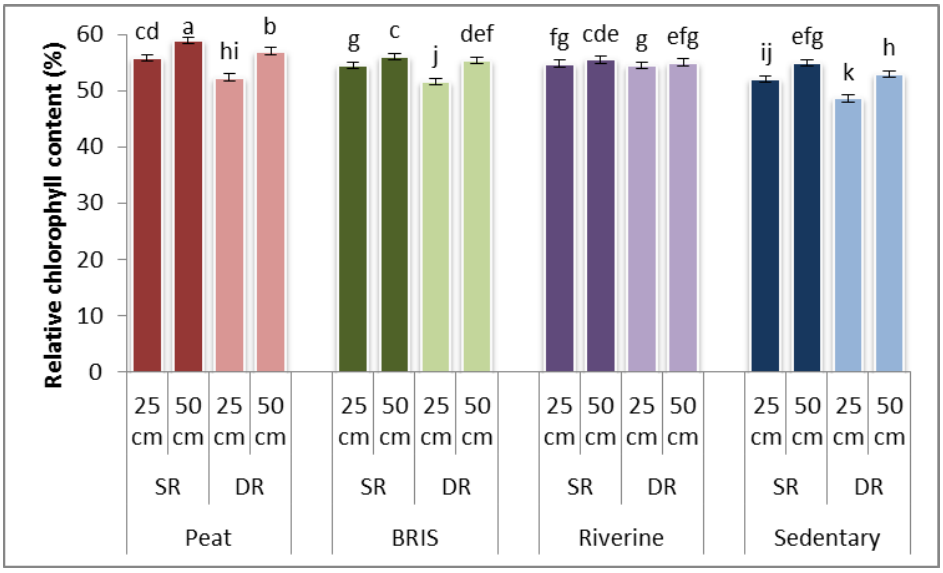

Fig. 8. Relative chlorophyll content (%) in the 8th sweet corn leaves from base of the plants at 8th WAP planted on different type of soils, plant arrangements (SR; Single row of plant arrangement, DR; Double row of plant arrangement) and planting distances.

Means with different letters is significantly different at P= 0.05 using LSD

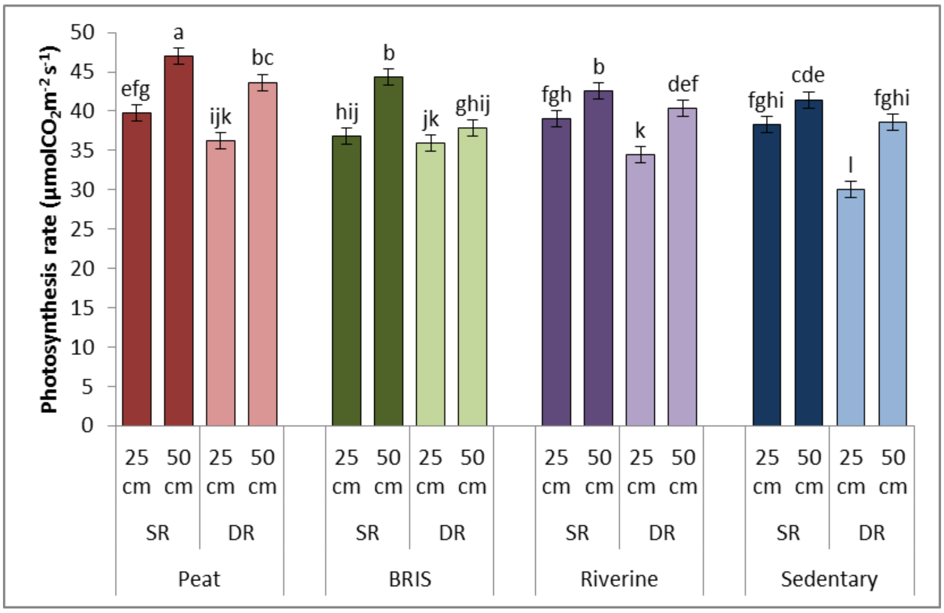

Fig. 9. Photosynthesis rate in the 8th sweet corn leaves from base of the plants at 8th WAP planted on different type of soils, plant arrangements (SR; Single row of plant arrangement, DR; Double row of plant arrangement) and planting distances

Means with different letters is significantly different at P= 0.05 using LSD

Planting distances significantly influenced the sweet corn plant growth. Increase in planting distance from 25 cm to 50 cm resulted in improvement of plant height and stem diameter, since it gives better plant distances and reduces competition between plants for growth factors such as water and nutrient, while narrowing planting distance will raises interplant competition. Enough growth factor caused the plant be able to grow optimally. The wide planting distance; 50 cm increases photosynthesis rate of the plant. Planting distances at 50 cm produced the highest in leaf area per plant that enables more water and nutrient uptake to the leaves and increase metabolic activity of the plant. Narrow planting distance at 25 cm results in lower growth rate. Planting distance at 25 cm causes the plant to grow taller and increase interplant competition which occur imbalanced growth factor distribution such as water and nutrient. It results in lower photosynthesis rate and leaf area per plant than 50 cm planting distance. At narrow planting distance; 25 cm planting distance, the plant inhibited to get the optimum growth factors. In addition, number and size of growth factors are influenced by number of nutrients available. Effendi DS, Taher S, Rumini W [39] agreed with the finding, the growth of two adjacent plants will not compete if there is enough groundwater and nutrient available for each plant. Finding of Ijoyah MO, Unah PO, Fanen FT [40] also in-line with this experiment, the widest planting distance at 30 cm produced the maximum photosynthesis rate and it gradually decreased with decreasing planting distance at 25 cm and 20 cm. The varying performance of plants with different level of planting distances agrees with the report of Madisa ME, Mathowa T, Mpofu C, Oganne TA [41] who reported that wider distance at 90 cm with lesser plant population revealed low leaf area index as compared to 75 cm, 60 cm, 45 cm and 30 cm with higher plant population that have higher leaf area index.

Peat at 1-row per bed plant arrangement at 25 cm planting distance produced the highest in total sugar content (16.25%). The interaction between these factors affects the sugar content in the kernels. Sweet corn planted at wider distance and higher soil's fertility produces higher sugar content. In this study, peat gave the highest total sugar content. At wider planting distance, plants enable to take better nutrients needed for the kernel quality. According to Radulov I et al, Lihiang A et al. [42,43], nutrients especially potassium are very crucial for increasing the sugar content of the sweet corn plant.

Table 6. Interaction effect of soil types, plant arrangements and planting distances on cob weight (g), cob length (cm), cob diameter (cm), number of rows per cob (NOR), number of kernels per row (NOK), thousand kernel's weight and total sugar content (%) of sweet corn

Treatment combinations	Cob weight (g)	Cob length (cm)	Cob diameter (cm)	NOR per cob	NOK per row	1000 kernel weight (kg)	Total sugar content (%)
BRIS: SR: 25	445.0gh	18.50fghi	5.30bc	16.20cde	39.58bcde	370.56fg	14.60fg
BRIS: SR: 50	521.6bcd	19.13de	5.28bc	15.35fg	40.98b	405.87bc	14.68efg
BRIS: DR: 25	430.5h	18.15hij	5.21c	16.95ab	41.23a	348.27h	14.31g
BRIS: DR: 50	511.4cde	18.45fghi	5.05d	15.78efg	38.53ef	387.39def	14.49fg
Riverine: SR: 25	501.5de	18.98defg	5.28bc	16.90ab	40.53abc	381.15ef	14.22h
Riverine: SR: 50	519.0cde	19.90bc	5.19c	16.78bc	39.25cdef	346.95h	15.40bcde
Riverine: DR: 25	434.5h	17.95ij	3.96f	15.48fg	39.63bcde	352.05h	14.26g
Riverine: DR: 50	519.0cde	19.58cd	5.04d	16.93ab	40.20abcd	400.90cd	14.47fg
Sedentary: SR: 25	439.0h	18.73efgh	3.65h	15.33fg	36.53g	360.54gh	15.55abcd
Sedentary: SR: 50	513.9cde	18.88efg	3.82g	15.48fg	38.20f	389.41cde	16.16ab
Sedentary: DR: 25	422.5h	17.78j	5.03de	17.58a	40.40abc	371.13efg	14.89defg
Sedentary: DR: 50	468.5fg	18.38ghij	3.90fg	16.00def	39.00def	371.13efg	15.60abcd
Peat: SR: 25	532.0bc	19.55cd	5.28bc	16.58bcd	38.78ef	420.16b	15.12cdef
Peat: SR: 50	586.9a	20.97a	5.66a	15.56efg	40.77ab	459.86a	16.25a
Peat: DR: 25	491.8ef	19.00def	5.38b	15.23g	40.53abc	372.80efg	13.35g
Peat: DR: 50	547.80b	20.27b	4.92e	15.98def	39.00def	442.24a	15.79abc
Mean	489.59	18.89	4.83	16.10	39.59	382.60	14.87
CV (%)	12.71	7.32	5.52	9.66	7.70	12.06	12.05

Means with different letters within each column is significantly different at P= 0.05 using LSD. TS; Type of soils, PA; Plant arrangements, PD; Planting distances; NOR; Number of rows, NOK; Number of kernels. SR; Single Row of Plant Arrangement, DR; Double Row of Plant Arrangement, 25; 25 cm Planting Distance, 50; 50 cm Planting Distance

Table 7. The interaction effect between type of soils, plant arrangements and planting distances on cob weight per hectare (kg/ha) of sweet corn

Treatment combinations	Plants/ha	Cob weight (kg/plant)	Cob weight (kg/ha)
BRIS: SR: 25	53,300	0.45gh	23,719k
BRIS: SR: 50	26,650	0.52bcd	13,901n
BRIS: DR: 25	106,600	0.43h	45,891c
BRIS: DR: 50	53,300	0.51cde	27,258h
Riverine: SR: 25	53,300	0.50de	26,730i
Riverine: SR: 50	26,650	0.52cde	13,831o
Riverine: DR: 25	106,600	0.44h	46,318b
Riverine: DR: 50	53,300	0.52cde	27,663g
Sedentary: SR: 25	53,300	0.44h	23,339l
Sedentary: SR: 50	26,650	0.51cde	13,695p
Sedentary: DR: 25	106,600	0.42h	45,039d
Sedentary: DR: 50	53,300	0.47fg	24,971j
Peat: SR: 25	53,300	0.53bc	28,356f
Peat: SR: 50	26,650	0.59a	15,641m
Peat: DR: 25	106,600	0.49ef	52,426a
Peat: DR: 50	53,300	0.55b	29,198e

Means with different letter within column is significantly different at P= 0.05 using LSD. SR; single row of plant arrangement, DR; Double row of plant arrangement, 25; 25 cm planting distance, 50; 50 cm planting distance

4. CONCLUSION

As a conclusion, results of this study confirms that there were significant differences in the plant growth, physiological attributes, and yield components of sweet corn grown on different soil types, plant arrangements and planting distances. This study indicates that the interaction between peat with 1-row plant arrangement at 50 cm planting distance; low plant density produced the highest in quantity per plant (kg/plant). This was reflected by higher growth rates, physiological attributes each individually plant. In contrary, the interaction between peat with 2-rows plant arrangement at 25 cm planting distance; high plant density produced the highest in quantity per hectare (kg/ha). This was due to the presence of more number of plants per unit area.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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