Journal of Applied Sciences Research, 9(2): 1161-1169, 2013
ISSN 1819-544X
This is a refereed journal and all articles are professionally screened and reviewed

ORIGINAL ARTICLES

Partition and Migration of Photosynthates in Newly Cultivated Grain Sorghum (*Sorghum bicolor* L.Moench) Grown under Sandy Soil in Egypt

[1]Ahmed, M.A., [2]Magda, A.F. Shalaby and [1]Ebtsam A. El-Housini

[1]Department of Field Crops Research, National Research Centre, Dokki, Giza.
[2]Botany Dept., National Research Centre, Dokki, Giza.

ABSTRACT

Two field experiments were carried out in newly cultivated sandy soil at New Salheyia Region, Sharkia Governorate in summer seasons of 2011 and 2012 on ten grain sorghum cultivars to study partition and migration of photosynthates in grain sorghum. Results can be summarized as follows: 1- Grain sorghum significantly differed in growth parameters at the different stages of growth, as well as, in yield and its components (except crop index).2-The ten grain cultivars differed significantly in photosynthates partitioning, where, significant differences were found in carbohydrate and protein percentages in vegetative organs and grains, oil percentage of grains as well as, in protein percentage in grains and straw yields. In addition, glucose required for synthesis of different chemical constituents of each vegetative organ, grains and straw, also, in carbon equivalent were significantly differed among the ten grain sorghum cultivar under investigation. Furthermore, cultivar differences in yield energy per plant or per fed for grains and straw yields, as well as, coefficient of energy of crop index and harvest index were significant, also in migration coefficient. 3- Highly and significant and positive correlation was found between grain yield / plant and each of weight of panicle, grain wt. /panicle , RPP_{gr} , migration coefficient, crop index , harvest index, plant height, blades area/plant and LAI . On the contrary, the relationships between grain yield /plant and Rpp_{veg} and Rpp_{bio} were negative and significant in RPP_{veg} only.4- Weight of panicle, migraine coefficient, grain wt./panicle and RPP_{gr} could contribute much of grain yield for grain sorghum cultivars since R^2 was 99.99 % of the variation .5- Harvested grain sorghum yield can be increased by growing Giza -115, Shandwel-2, Shandwel-6, Hybrid-302,Hybrid-304. Hybrid-305 and Hybrid-306 where these cultivars characterized by their highest values from vegetative growth, yield and its components and photosynthates portioning and migration towards the economic yield compared with the other three cultivars under study Giza-13,Pioneer and Dorado.

Key words:

Introduction

Grain sorghum (*Sorghum bicolor* L.Moench) is one of the most important crops in the world .It is considered the fourth cereal crops after maize, wheat and rice (Agric. Econ. Year Book, 1995). Such crop can yield reasonably well under adverse conditions of low irrigation. It is grown different part of the tropical and subtropical regions in the world. In Egypt is concentrated in the middle and upper parts.

The introduction of the new tall cultivars (Giza-15 and Giza-113), the semi-tallest cultivars (Shandauil-1, Shandwel-2 and Shanduil-6, Hybrid-301, Hybrid-302, Hybrid-304, Hybrid-305 and Hybrid-306) and the shorted cultivars (Pioneer and Dorado) has resulted in an increases yielding ability when growing under modern production techniques.

The yield potential of grain sorghum plant can be defined as the total biomass produced or the agricultural important part of the grain sorghum (i.e. grain yield). The total biomass is a result of the integration of metabolic reaction of the plant. Consequently, any factor influencing the metabolic activity of the plant at any period of its growth can affect the yield. Metabolic processes in grain sorghum plant are greatly governed by both internal; i.e. genetic make up of the plant and external condition which involve tow main factors namely climatic and edaphic environmental factors. Furthermore, the yield potential of grain sorghum could be regulated through alternation of genetic make up and the reconstitution of genetic structure through breeding program and or by modification of environment through improving cultural treatments. However, Egyptian grain sorghum cultivars may differ in their assimilating capacity and distribution could be referred as Source and Sink relationship.

The objective of this study was to analyze the growth and development of grain sorghum cultivars, a high yielding cultivar recently in widespread use in Egypt, to determine the plant factors affecting yield. Too often researches have studied only in terms of final harvest. In this study, the growth and development of the plant was studied at fifteen days intervals stating from 65 days up to 95 days after sowing to determine how the yield

Corresponding Author: Ahmed, M.A., Department of Field Crops Research, National Research Centre, Dokki, Giza.

component developed. It is hoped that through our results, area of possible improvement may be shown which could help plant breeder in the development of future higher yielding grain sorghum cultivars.

Material and Methods

Ten grain sorghum cultivars, i.e. Giza-15, Giza-113, Shandwil-2, Shandwil-6, Hybrid-302, Hybrid-304, Hybrid-305, Hybrid-306, Pioneer and Dorado were cultivated in two field experiments in newly cultivated sandy soil at New Salhyia Region.Sharkia Governorate in a complete randomized block design with six replication in summer seasons of 2011 and 2012. Three replication were adapted for vegetative growth studies and the rest for yield and its components. The soil type was sand texture with pH value 7.9, contained 0.49 organic matter and contained 46 ppm available N, 10.85ppm available P and 139.3 ppm available K. The experimental unit contained seven ridges, five meters along and 60 cm apart. Plants were done in hill spaced 20 cm along, Thinning to two plants per hill after 20 days from planting date. Nitrogen fertilizer was applied at a rate of 80 kg N/fed in four equal doses at seven days intervals starting from 20 days after planting(i.e.20,27,34 and 41days after planting). Irrigation, pest control and other cultural practices were carried out as recommended. Planting data were on May 25 st in the seasons. Samples of ten guarded plants were taken at random for growth measurements: plant height cm^{-}, number of actives/plant, stem + sheats dry weight/plant g^{-} , blades dry weight/plant g^{-}, panicle dry weight g^{-}, blades area cm^{2} /plant (according to Bremner and Taha,1966)and leaf area index (as recommended by Watson, 1952).

Yield measurement:

At harvest ten guarded plants were taken out at random for the middle two ridges of each plot to determine yield attributes, i.e. plant height, weight of panicle g^{-} , weight of grains g/panicle, straw yield/plant, and above ground biomass/plant. Moreover, grain, straw and biological yields (Ton/fed.)were calculated for the plot area and then converted to yield per fed., where migration coefficient, crop index and harvest index were determined according to Abdel- Gawad *et al* (1987). Relative photosynthetic potential (RPP) for biological and grains yields and vegetative organs were calculated according to the method described by Vidovic and Pokorny (1973).

To study photosynthetic partitioning in the above previous ten grain sorghum cultivars, crop growth rate (CGR mg/cm^{2} /days) was determined by multiplying NAR $\times$LAI according to Abdel-Gawad *et al* (1987). In addition the percentage of carbohydrate and protein were estimated in vegetative organs and straw and oil %in grains. The total carbohydrate (%) in different organs was determined according to the methods shown by Dubios *et al* (1956). Total nitrogen (%) was determined according to AOCS (1984) and was multiplied by 6.25 to calculate protein (%). Crude oil (%) was determined using the method described by AOCS (1980). Although plant composition changes with the age, these values may be fairly enough to provide an estimate of the partitioning coefficient. To calculate the photosynthates required to produce the different constituents, carbon equivalent was determined as shown by Hanson *et al* (1960). The production value (PV) of the previous plant components was determined according to Penning De Vries *et* al (1974). The conversion factor to estimate carbon equivalent, production value, glucose required for synthesis, stored grams, work carbon required in synthesis for carbohydrate, protein, and oil in the different plant components was used as reported by Hanson *et al* (1460), as well as, energy coefficient of crop index and crop energy of harvest index were calculated according to Abdel-Gawad *et al* (1987). In addition, energy per plant and per fed. at harvest was calculated using caloric factors according to Hanson *et al* (1960). Combined analysis was made for the two growing seasons as results followed similar results according to Snedecor and Cochran (1982). For comparison between means, LSD test at 5% level was used. Furthermore, simple correlation coefficient for all possible combinations between plant yield and means of the characters after anthesis (i.e. 95 days after planting) were practiced according to Neter and Wasserman (1974).

Simple correlation of cource do not primt the estimation of different effects of particular yield factor such as plant height, grain weight/panicle grain index, RPP_{gr} RPP_{bio} and blades area/plant or any other factor, since the variable is in some way associated with one or more variable which are in turn associated with yield. Therefore, the path coefficient analysis which measures, the direct influence of one variable upon another and primts the separation of possible correlation coefficient into components of direct and indirect effects, was done according to Wright (1934) and Snedecor and Cochran (1982).

Results and Discussion

Growth analysis:

The results reported in Table (1) showed significant differences among ten grain sorghum cultivars under study, the two tall cultivars Giza-15 and Giza-113, the six average length cultivars Shandwel-2, Shandwel-6, Hybrid-306 and the two short cultivars Pioneer and Dorado in growth parameters at 65, 80 and 95 days after sowing. Furthermore, plant height and panicle dry weight /plant for all cultivars tended to increase with advance of plant age up to 95 days after sowing, meanwhile, number of leaves/plant, stem+ sheats dry weight/plant, blades dry weight/plant, blades area/plant and LAI tended to decrease with advance of plant age after 80 days after sowing. It is worthy to mention that Giza-15 and Giza-113 gave the highest significant plant height, stem+ sheats; blades and panicle dry weight/plant compared with Shandwel-2, Shandwel-6,Hybrid-302,Hybrid-304,Hybrid-305,Hybrid-306,pioneer and Dorado cultivars,meanwhile,Shandwel-2 and Hybrid-306 exceeded other eight grain sorghum cultivars in number of blades/plant, blades area/plant and LAI during the different growth stages.

It is worthy that difference in growth stages are in a good agreement with results obtained by Selim(1995), El-Hattab *et al* (2000), El-Gazzar (2003), Ahmed *et al* (2007) and Hassanein *et al* (2010). Furthermore, cultivar differences in growth parameters in this study may be due to differences in genetic structure, in addition, to the widely differences between genotypes for mineral element concentrations (Clarch *et al*,1997) and to the cultivar differences in photosynthate partitioning and migration among plant organs (El-Gazzar, 2003) and, Saleh *et al* 2011, and Ahmed *et al*, 2011).

Table 1: Effect of cultivar differences on growth parameters of ten sorghum cultivars.

Cultivars	Tall cultivars		Average length cultivars						Short cultivars		LSD
Plant age (days)	Giza-15	Giza-113	Shandwil 2	Shandwil 6	Hybrid 302	Hybrid 304	Hybrid 305	Hybrid 306	Pioneer	Dorado	5%
Plant height cm^{-}											
65	262.80	226.9	133.5	135.9	134.0	133.0	134.0	137.24	109.81	115.22	10.6
80	296.65	249.83	152.2	161.43	158.48	153.3	155.8	172.31	115.76	126.9	9.8
95	348..89	313.9	181.11	186.16	183.1	178.22	181.3	183.65	123.33	143.6	10.05
Number of leaves/plant											
65	15.8	16.33	16.67	17.34	16.48	16.5	17.0	18.00	14.67	15.0	0.24
80	16.4	17.67	17.33	18.33	17.52	17.67	17.67	18.67	15.33	16.0	0.12
95	15.5	16.00	17.17	18.00	17.0	17.0	17.33	18.33	15.0	15.3	0.36
Stem + sheats dry weight g/plant											
65	34.99	31.94	14.91	17.26	15.68	14.84	16.54	18.29	11.42	13.54	0.37
80	47.81	43.00	17.85	20.96	18.92	18.03	19.86	21.76	13.91	16.88	0.72
95	36.02	32.60	16.29	18.72	17.65	16.35	18.04	20.14	12.28	14.10	0.43
Blades dry weight g/plant											
65	9.44	8.96	7.29	7.70	7.64	7.18	7.49	7.88	6.62	7.25	0.26
80	12.83	10.85	8.03	8.47	8.28	7.89	8.20	8.61	6.98	7.62	0.36
95	10.87	9.79	7.56	7.80	7.86	7.48	7.75	8.04	6.81	7.49	0.28
Panicle dry weight g/plant											
65	7.79	9.41	7.34	7.18	7.03	6.84	6.93	7.52	6.96	7.38	1.59
80	44.83	50.77	37.81	35.45	33.18	30.52	31.87	39.88	18.36	26.10	2.08
95	75.63	88.50	63.10	60.94	59.11	58.05	58.19	65.02	51.90	63.44	1.62
Blades area cm^2/plant											
65	1649.5	1863.0	1920.73	1835.0	1736.2	1683.0	1709.4	1988.5	1385.42	1464.11	17.43
80	2081.9	2105.0	2152.85	2030.7	1908.0	1773.2	1836.0	2239.85	1467.28	1530.90	15.11
95	1754.0	1802.5	2010.5	1913.82	1840.0	1682.3	1727.0	2118.0	1420.10	1444.0	19.90
Leaf area index (LAI)											
65	2.75	3.11	3.20	3.06	2.89	2.81	2.85	3.31	2.31	2.44	0.02
80	3.47	3.51	3.59	3.38	3.18	2.96	3.06	3.73	2.45	2.55	0.08
95	2.92	3.00	3.35	3.19	3.07	2.80	2.88	3.53	2.37	2.41	0.06
Crop growth rate (mg/cm^2/day)											
65-80 days age	5.16	8.41	9.40	7.87	7.23	6.33	6.92	9.81	5.30	5.59	0.12
80-95 days age	4.1	6.49	8.02	6.18	6.02	5.62	5.75	8.23	4.25	4.44	0.11

(Average of 2011 and 2012 seasons)

2- Cultivar differences in yield its components:

There were significant differences between the ten grain sorghum cultivars under study Giza-15, Giza-113, Shandwel-2, Shanwel-6, Hybrid-302,Hybrid-304,Hybrid-305, Hybrid-306, Pioneer and Dorado in plant height, weight of panicle, grain weight/panicle, shelling%, grain index 100 grains wt/g, straw yield/plant, biological yield/plant, RPP $_{gr}$, RPP $_{bio}$, RPP $_{veg}$, grain; straw and biological yields/fed., harvest index and migration coefficient, meanwhile, the differences in crop index failed to reach the significant level at 5% (Table 2).Furthermore, data recorded in the same table observed that Shandwel-2 and Hybrid-306 significantly surpassed other eight cultivars under study in each of weight of panicle, grain wt./panicle, straw yield/plant, biological yield/plant, On the other hand the greatest, plant height and grain index collected by Giza-15 and

Giza-113 Pioneer and Dorado cultivars had the highest significant values from RPP $_{gr}$, RPP $_{bio}$, RPP $_{veg}$ compared with other cultivars under study . With respect to grain yield/fed. and biological yield/fed.; yielded by hybrid -305 and hybrid-306 gave highest value for the two these components, while Giza-15 and Hybrid-306 harvested the greatest value from straw yield/plant. In addition, Hybrid-305 and Hybrid-306 had the height biological yield/fed, whereas, Shandwel-6 and Hybrid-302 produced the greatest crop index and harvest index compared with other cultivars under study. With respect of migration coefficient; Hybrid-304 and Hybrid-305 characterized with greatest value from this coefficient compared with other cultivars.

Cultivar differences in yield and its components in this study are in harmony with the results obtained by Selim (1995), El-Hattab *et al (*2000). El-Gazzar (2002), Ahmed *et al* (2007) and Hassanein *et al* (2011). Moreover, these cultivar differences may be attributed to differences in genetic structure between the ten cultivars in this study, also to cultivar differences in growth characters (Table 1), and to the cultivar differences photosynthate partitioning that found in the following part of this study (Tables3and 4) that previously indicated by (El-Gazzar, 2003, Saleh et al, 2011 and Ahmed *et al*, 2011).Also, to the widely differences between genotypes for mineral concentrations that found by Clark *et al* (1997) can be attribute the hybrid differences in yield and its components.

The significant superiority of shandwel – 2 and Hybrid – 6 in weight of panicle , grain at / panicle , straw yield and biological yield over other eight grain sorghum cultivars may be due to the high yielding cultivar had a more vigorous system in generation reducing potential during plant growth than did the less productive cultivar and the higher yielding cultivar has a higher photosynthetic electron transport chain potential, which is a genetically character, more than lower yielding cultivar (Voldarskii *et al* , 1978).

In addition, the greatest grain wt. /plant may explain its higher yield as panicle are more effective sink for the carbohydrate synthesized in the leaves with fewer and large grains (Frisher *et al*, 1966).

The greatest value of blade area /plant, LAI and CGR in shandwel-2 and Hybrid -306 my own much the high potential efficiency of these two cultivars in grain yield.

It is noteworthy to mention that Pucridge (1971) reported that changes in LAI caused a variation in CO_2 uptake and the difference in grain yield from anthesis onwards were correlated with LAI and CO_2 uptake , thus , the cultivar difference in LAI in Table (1) my be a cause cultivar difference in grain yield.

Table 2: Effect of cultivar differences on yield and its components (Average of 2011 and 2012 seasons).

Cultivar	Tall cultivars		Average length cultivars						Short cultivars		LSD 5%
Yield and its components	Giza-15	Giza-113	Shandwil 2	Shandwil 6	Hybrid 302	Hybrid 304	Hybrid 305	Hybrid 306	pioneer	Dorado	
Plant height cm	331.18	289.60	179.43	181.52	176.21	165.10	172.63	178.0	113.14	139.85	6.24
Weight of panicle gm	115.92	136.50	142.68	140.43	139.62	138.0	139.43	151.20	120.9	127.8	1.85
Grain wt./panicle gm	89.22	100.40	114.63	109.28	106.51	102.54	104.76	117.39	97.13	100.06	2.61
Shelling %	0.77	0.74	0.80	0.78	0.76	0.74	0.75	0.78	0.80	0.78	0.02
Grain index	20.83	22.78	18.92	17.93	17.64	16.99	17.35	19.75	18.23	19.74	0.29
Straw yield g/plant	117.39	110.59	117.72	112.25	108.20	104.79	107.78	125.05	97.93	10.08	7.39
Biological yield g/plant	206.61	210.99	231.35	221.53	214.71	207.31	211.54	242.44	194.06	200.14	8.88
RPP $_{gr}$ (g/plant /LAI)	27.88	30.80	33.03	33.13	34.03	35.60	36.50	32.34	40.30	40.35	0.04
RPP $_{bio}$(g/plant /LAI)	64.56	64.72	66.96	67.33	68.60	71.98	73.71	66.79	80.52	80.70	0.17
RPP $_{veg}$(g/plant /LAI)	36.69	33.92	33.93	34.20	34.57	36.38	37.21	34.45	40.22	40.35	0.13
Grain yield Ton/fed.	2.44	2.76	3.15	3.27	3.37	3.18	3.45	3.59	2.61	2.98	0.12
Straw yield Ton/fed.	3.46	3.29	3.09	3.18	3.23	3.29	3.37	3.56	2.92	3.03	0.08
Biological yield Ton/fed.	5.90	6.05	6.24	6.45	6.60	6.47	6.82	7.15	5.53	6.01	0.14
Crop index	0.41	0.46	0.50	0.51	0.51	0.47	0.51	0.50	0.47	0.50	n.s
Harvest index	0.71	0.84	1.02	1.03	1.04	0.97	1.02	1.01	0.89	0.98	0.01
Migration coefficient	0.56	0.65	0.61	0.63	0.65	0.67	066	0.62	0.62	0.64	0.01

Photosynthates Partitioning:

The partitioning coefficient would be determined by the capacity of the photosynthetic sink created by the panicle. When plants reached the final weeks of grain filling period (soft dough stage to ripe stage) the coefficient of partitioning may increase. Evidence for these is shown by very rapid decline in the canopy in the final weeks and the possible scavenging nutrients from the vegetative plant parts.

There were significant differences between grain sorghum cultivars in crop growth rate (Table 3) and panicle dry weight at different stages of growth (Table 1).

Furthermore, Giza-113, Shandwel-2 , Shandwel-6, Hybrid 302 and Hybrid-306 exceeded the cultivars Giza -15, Hybrid -304, Hybrid- 305, Pioneer and dorado cultivars in CGR and panicle dry weight Plant (Table1). Again crop growth rate tented to decrease with advancing age From 80 to 90 days after sowing (Table1). On the other hand, panicle dry weight plant tended to increased linearly From 65 days after planting (Table1).

It is worthy to mention that CGR values of vegetative organs reflect the total amount of photosynthate partitioned into the yield components. The partitioning coefficient can not approximated from a simple ratio of the slope of crop growth rate since more photosynthate is required to produce a given amount of grains than the some amount of vegetative material. The additional photosynthate is required to produce the additional protein and oil in grains (Hanson etal, 1960, Penning Devries *et al* .1974, McGraw, 1977, Ahmed *et al* 2011 and Saleh *et al*, 2011).

To estimate the amount of photosynthate need to produce a quantity of panicle in the same quantity of vegetative material, the relative quantities of carbohydrate, protein and oil should be detected .Significant differences were found among the ten grain sorghum cultivars in carbohydrate and protein in vegetative organs, kernels and straw, also in oil percentage in grains (Table3). Furthermore, Shandwel-2 and hybrid-306 significantly outweighed the other ten cultivars, i.e. Giza-15 Giza-113, Shandwel-6, Hybrid 302, Hybrid-304, Hybrid-305, Pioneer and Dorado in carbohydrate, protein percentages per vegetative organs, kernels and straw and oil percentage per grains, Data reported. In Table (3) shows. That glucose required for synthesis of the chemical compounds by the various grain sorghum cultivars components. Differences among maize hybrids in glucose required for synthesis of carbohydrate in vegetative organs, grains and straw, of protein in vegetative organs and grains, as well as, of oil in grains. On the other hand, cultivar differences in glucose required of protein in straw failed to reach the significant level at 5%. Hybrid-306 required more glucose for synthesis of carbohydrate and protein in vegetative organs, grains and straw, as well as, oil in grains.

With respect of carbon equivalent, according to Hanson *et al* (1960), carbon equivalent is defined the gram atom of the sugar carbon required to produce product including both gram atoms of work carbon lost in the synthesis and gram atoms of carbon stored in the product. Data in Table (3) revealed significant differences among grain sorghum in carbon equivalent for each of carbohydrate and protein of vegetative organs and straw, whereas the differences in carbon equivalent for oil of grains were not significant. In addition, Hybrid-306 characterized with a high carbon equivalent for carbohydrate and protein of vegetative organs, and grains, whereas, Shoundwel-2 had the high significant value from carbon equivalent for carbohydrate of straw meanwhile Hybrid 306 and Pioneer gave the greatest value from carbon equivalent for protein of straw, compared with other cultivars under study.

Generally, there were significant differences among the ten grain sorghum cultivars under this study in yield energy per plant and per fed. , where cultivars differed significantly in energy yield of carbohydrate, protein and oil. In addition, Hybrid-306 significantly outweighed other nine cultivars under study in energy yield of carbohydrate and protein in grains and straw, as well as oil in grains per plant and per fed. Hence, Hybrid-306 characterized by its significant superiority in total energy of grains and straw per plant and per fed. (Table4).

Table 3: Effect of sorghum cultivar differences in chemical components, glucose required for synthesis and carbon equivalent (Combined analysis of 2011 and 2012 seasons)

Cultivars	Tall cultivars		Average length cultivars						Short cultivars		LSD 5%
Plant organs	Giza-15	Giza-113	Shandwel 2	Shanwel 6	Hybrid 302	Hybrid 304	Hybrid 305	Hybrid 306	pioneer	Dorado	
Vegetative organs	Carbohydrate, protein and oil percentage										
Carbohydrate	67.4	68.6	71.83	69.88	70.5	68.9	69.63	72.78	67.2	68.54	1.02
Protein	9.28	9.78	10.06	10.00	9.6	9.77	10.11	10.52	9.34	9.40	0.07
Grains											
Carbohydrate	75.63	76.03	80.15	78.79	76.88	78.6	77.81	81.8	75.34	78.17	1.59
Protein	9.39	9.77	10.11	10.52	10.63	10.64	10.90	11.12	9.65	9.87	0.19
Oil	4.47	4.6	4.6	5.1	4.80	4.80	4.60	4.95	4.0	4.1	0.11
Straw											
Carbohydrate	70.67	71.7	71.83	76.03	70.11	71.52	75.63	77.81	72.79	71.54	1.09
Protein	8.43	9.15	9.28	9.28	8.78	9.05	9.28	9.34	9.25	9.08	0.01
Vegetative organs	Glucose required for Carbohydrate, protein and oil synthesis										
Carbohydrate	0.79	0.804	0.842	0.819	0.829	0.808	0.816	0.853	0.788	0.804	0.009
Protein	0.15	0.158	0.162	0.161	0.155	0.158	0.163	0.170	0.151	0.15	0.001
Grains											
Carbohydrate	0.887	0.891	0.94	0.92	0.90	0.92	0.912	0.959	0.883	0.916	0.016
Protein	0.151	0.158	0.163	0.17	0.172	0.172	0.172	0.179	0.163	0.168	0.005
Oil	0.127	0.13	0.13	0.17	0.14	0.14	0.13	0.141	0.11	0.12	0.015
Straw											
Carbohydrate	0.83	0.84	0.842	0.891	0.822	0.838	0.887	0.912	0.85	0.84	0.021
Protein	0.14	0.15	0.15	0.15	0.142	0.146	0.15	0.15	0.15	0.15	n.s
Vegetative organs	Carbon equivalent										
Carbohydrate	28.96	27.44	28.73	27.95	28.28	27.56	27.85	29.11	26.88	27.42	0.16
Protein	7.29	7.69	7.91	7.86	7.55	7.68	7.91	8.27	7.34	7.39	0.14
Grains											
Carbohydrate	28.26	28.41	28.95	28.95	28.67	28.95	28.69	32.72	28.11	28.49	0.50
Protein	7.38	7.68	7.95	8.27	8.36	8.36	8.57	8.74	7.59	7.84	0.14
Oil	5.11	6.86	6.86	6.86	5.48	5.48	6.86	6.86	6.86	6.86	n.s
Total	40.75	42.95	43.76	44.08	42.51	42.94	44.12	48.32	42.56	43.19	
Straw											
Carbohydrate	28.27	28.68	28.73	28.41	28.04	28.61	28.63	28.69	28.12	28.62	0.03
Protein	6.63	7.20	7.29	72.9	6.90	7.14	7.29	7.35	7.35	7.14	0.04
Total	34.9	35.88	36.02	35.70	34.94	35.75	35.92	36.04	35.47	35.76	0.21

It is worthy that data reported in Table (4) showed that the cultivar differences in energy coefficient of crop index was not significant but was significant in energy coefficient of harvest index. Hybrids 302 and 304 had the highest significant value from energy coefficient of harvest index.

Thus, it is could be concluded that our present results are in harmony with the results obtained by El-Gazzar (2002), Ahmed *et al* (2011) and Saleh *et al (2011)*,where they indicated that cultivar differences in partitioning and migration of the total available photosynthetic to economic yield in carbon equivalent for vegetative organs, straw, yield energy of grains and straw per plant and per fed. and energy coefficient of crop index and harvest index.

Table 4: Hybrid differences in energy yield per plant and per fed. at harvest of ten grain sorghum cultivars. (Combined analysis of 2011 and 2012 seasons).

Cultivars	Tall cultivars		Average length cultivars						Short cultivars		LSD 5%
Plant organs	Giza-15	Giza-113	Shandwel 2	Shanwel 6	Hybrid 302	Hybrid 304	Hybrid 305	Hybrid 306	pioneer	Dorado	
	Yield energy/plant at harvest K cals.										
Grains: Carbohydrate	266.53	302.59	362.91	340.10	323.45	318.35	321.98	379.3	289.05	308.96	6.42
Protein	38.29	44.83	52.96	52.53	51.74	49.86	52.18	59.66	42.83	45.13	5.08
Oil	37.49	43.41	49.57	52.38	48.06	46.27	45.30	54.62	36.52	38.56	2.05
Total	342.31	390.83	465.44	445.01	423.25	414.25	419.46	493.58	368.40	392.65	14.90
Straw :											
Carbohydrate	327.69	332.12	334.01	337.11	302.63	296.04	321.98	384.34	281.57	282.81	1.03
Protein	45.22	49.38	49.92	47.60	43.85	43.34	45.71	53.38	41.84	42.44	2.19
Total	372.91	381.50	383.93	384.71	346.48	339.38	367.69	437.72	323.47	325.25	20.15
	Yield energy/ fed. at harvest 10^{6} K cals										
Grains: Carbohydrate	7.29	8.29	9.97	10.18	10.23	9.87	10.60	11.60	7.77	9.20	0.47
Protein	1.05	1.23	1.46	1.58	1.64	1.55	1.72	1.82	1.15	1.34	0.08
Oil	1.03	1.19	1.34	1.57	1.52	1.43	1.49	1.67	0.98	1.15	0.06
Total	9.37	10.71	12.77	13.33	13.39	12.85	13.81	15.09	9.90	11.69	0.71
Straw											
Carbohydrate	9.66	8.29	8.77	9.55	8.94	9.29	10.07	10.94	8.40	8.56	0.55
Protein	1.33	1.38	1.31	1.35	1.30	1.36	1.43	1.52	1.25	1.26	0.07
Total	10.99	9.67	10.08	10.90	10.24	10.65	11.50	12.46	9.65	9.82	
Energy Coefficient											
Energy Coefficient of crop index	0.48	0.51	0.55	0.54	0.55	0.55	0.53	0.53	0.53	0.55	n.s
Energy Coefficient of harvest index	0.92	1.02	1.21	1.16	1.22	1.22	1.14	1.13	1.14	1.21	0.01

Again, as mentioned before, harvested grain sorghum yield can be increased by growing Giza-115; Shandwel-6, Hybrid-302, Hybrid-304, Hybrid-305 and Hybrid-306 cultivars that characterized by its highest efficiency in partitioned and migration of photosynthates towards economic yield.

Correlation studies:

Estimates of simple correlation coefficient between grains yield and some yield components and growth characters of ten grain sorghum cultivars are presented in Table (5). Data observed clearly highly significant positive relationship between grains yield /fed. and each of wt. of panicle, grain wt. /panicl, RPP $_{gr}$, migration coefficient, crop index, harvest index, plant height, blades area/plant and LAI, between wt. of gr panicle/plant and rain wt./panicle, RPP $_{gr}$, migration coefficient. crop index, harvest index, plant height, blades area/plant and LAI, and between grain wt. / panicle and RPP $_{gr}$, shelling %, migration coefficient, crop index, harvest index, plant height, blades area /plant and LAI. Also the simple correlation coefficients between shelling% and harvest index and blades area, between LAI and migration coefficient, crop index and blades area and between plant height and blades area were positive and highly significant.

On the other hand, positive and significant simple correlation coefficients were found between shelling% with grain yield/fed. and wt. of panicle, between RPP $_{bio}$ and plant height and LAI. (Table5).

On the contrary, a high significant negative relationship were detected between RPP $_{veg}$ and each of RPP $_{gr}$, migration coefficient, harvest index and blades area/plant, whereas, a significant negative correlations were reported between RPP $_{veg}$ and grain yield/fed, and grain wt./ panicle, between RPP $_{bio}$ and harvest index as well as blades area (Table 5).

It is worthy to mention that the simple correlation coefficient for the rest possible combination between grain yield and previous measurements were positive and insignificant, except between RPP $_{veg}$ and wt of panicle/plant, shelling% and migration coefficient, between RPP $_{bio}$ and grain yield/fed, wt. of panicle/plant grain wt./panicle, RPP $_{gr,}$ shelling% and migration coefficient, between harvest index and plant height and blades area/plant, also, between LAI and shelling%, and between plant height and blades area /plant were negative and insignificant.

Path coefficient analysis:

Table (6) reveals that partitioning of average of simple correlation coefficient between grains yield / fed. and some yield component as well as some growth characters as the average of ten sorghum cultivars under study. Weight of panicle /plant proved to have a high direct effect on grain yield compared with migration coefficient, grain wt/panicle and plant height meanwhile RPP$_{gr}$ had a high negative direct effect on grain yield compared with LAI Since the average means of the direct effect were 0.583, 0.303, 0.155, -0.205 and -0.107 for these six components, respectively. Again, as mentioned before (Table 5), total correlation coefficient was most

J. Appl. Sci. Res., 9(2): 1161-1169, 2013

pronounced in the weight of panicle/plant (r = 0.996), then in grain wt. /panicle (r = 0.98), migration coefficient (r = 0.91), RPP_{gr} (r = 0.87), LAI (r = 0.67) and plant height (r = 0.63).

Table 5: Correlation coefficient between sorghum grain yield and some yield components and some growth characters.

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
Grain yield / fed X1		0.996**	0.98**	-0.41*	-0.15	0.87**	0.47*	0.91**	0.58**	0.58**	0.63**	0.66**	0.67**
Weight of panicle /plant X2			0.98	-0.39	-0.16	0.87**	0.46*	0.90**	0.59**	0.57**	0.61**	0.66**	0.65**
Grain weight / panicle X3				-0.44*	-0.23	0.83**	0.53**	0.85**	-0.54**	0.66**	0.52**	0.69**	0.56**
RPP_{veg} g/LAI X4					0.28	-0.58**	-0.22	-0.52**	-0.17	-0.75**	0.23	-0.83**	0.19
RPP_{bio} g/LAI X5						-0.24*	-0.34	-0.15	0.21	-0.44*	0.46*	-0.47**	0.44*
RPP_{gr} g/LAI X6							0.25	0.37	0.12	0.02	0.28	0.25	0.32
Shelling % X7								0.72**	0.34	0.90**	0.09	0.72	-0.05
Migration coefficient X8									-0.60**	0.66**	0.48*	0.34	0.57**
Crop index X9										0.20	0.58**	0.90**	0.59**
Harvest index X10											-0.16	0.72**	-0.11
Plant height X11												-0.09	0.61**
Blades area/plant X12													0.99**
LAI X12													

(Average of 2011 and 2012 seasons)

Table 6: Path coefficient analysis of grain yield for grain sorghum.

Source	Correlations	Source	Correlations
Grain yield /plant via weight of panicle /plant		Grain yield /plant via. Migration coefficient	
Direct effect	0.583	Direct effect	0.303
Indirect effect via grain wt./panicle	0.294	Indirect effect wt. of panicle/plant	0.525
Indirect effect via RPP_{gr}	-0.178	Indirect effect via grain wt./panicle	0.255
Indirect effect via Migration coefficient	0.273	Indirect effect via RPP_{gr}	0.201
Indirect effect via plant height	0.095	Indirect effect via plant height	0.089
Indirect effect via LAI	-0.075	Indirect effect via LAI	-0.065
Total	0.996	Total	0.91
Grain yield / plant via wt./panicle		Grain yield / plant height	
Direct effect	0.300	Direct effect	0.155
Indirect effect via grain wt./panicle	0.571	Indirect effect via grain wt./panicle	0.355
Indirect effect via RPP_{gr}	-0.170	Indirect effect via RPP_{gr}	0.156
Indirect effect via Migration coefficient	0.258	Indirect effect via Migration coefficient	-0.100
Indirect effect via plant height	0.081	Indirect effect via plant height	0.172
Indirect effect via LAI	-0.060	Indirect effect via LAI	-0.106
Total	0.980	Total	0.63
Grain yield /plant via RPP_{gr}		Grain yield /plant via LAI	
Direct effect	-0.205	Direct effect	-0.107
Indirect effect via wt. of panicle/plant	0.507	Indirect effect via grain wt./panicle	0.379
Indirect effect via grain wt./panicle	0.249	Indirect effect via RPP_{gr}	0.168
Indirect effect via Migration coefficient	0.297	Indirect effect via RPP_{gr}	-0.107
Indirect effect via plant height	0.075	Indirect effect via migration coefficient	0.185
Indirect effect via LAI	-0.056	Indirect effect via plant height	0.154
Total	0.870	Total	0.67

J. Appl. Sci. Res., 9(2): 1161-1169, 2013

Table (7) shows that direct effect of weight of panicle/plant was 14.75%, being higher than that of migration coefficient (3.99%), grain wt. /panicle(3.9%), RPP_{gr} (1.82%), plant height (1.04%) and LAI (0.48%). The joint effect of weight of panicle with grain wt. / panicle, RPP_{gr} migration coefficient, plant height, and LAI amounted to 14.88%, 9.02%, 13.8%, 4.82% and 3.56% of the variation respectively. The joint effect of grain weight/ panicle with RPP_{gr} , migration coefficient, plant height and LAI were amounted 4.43%, 6.72% and 2.134 and 1.56 ,of the variation, respectively, whereas the joint effect of RPP_{gr} with migration coefficient, plant height and LAI were 5.29%,1.34% and 1.00% of the variation, respectively. Regarding the joint effect migration coefficient with plant height and LAI amounted 2.34% and 1.69% of the variation; respectively, meanwhile the joint effect of plant height with LAI was 1.43 of the variation.

As mentioned before, weight of panicle, migration coefficient, grain weight /panicle a RPP_{gr} were the most effective in contributing to grain yield since the direct effect was 14.75%, 3.99, 3.90% and 1.82% of the variation, respectively, whereas the joint effect of weight of panicle and each of grain weight/panicle, migration coefficient and RPP_{gr} were amounted 14.88%, 13.8 % and 9.02% of the variation, respectively.

Here, the four parameters, i.e. weight of panicle, migration coefficient, grain weight/panicle and RPP_{gr} could contribute much of grain sorghum yield since R^2 was 99.99% of the total variation.

Table 7: Coefficient of determination and percentage contribution to grain sorghum yield.

Characters	C.D	% contribution
Weight of panicle	0.34	14.75
Grain wt./panicle	0.09	3.9
RPP_{gr}	0.042	1.82
Migration coefficient	0.092	3.09
Plant height	0.024	1.04
LAI	0.011	0.48
Wt. of panicle × grain wt./panicle	0.343	14.88
Wt. of panicle × RPP_{gr}	-0.208	9.02
Wt. of panicle × migration coefficient	0.318	13.8
Wt. of panicle × plant height	0.111	4.82
Wt.of panicle × LAI	-0.082	3.56
Grain wt / panicle × RPP_{gr}	0.012	4.43
Grain wt / panicle × migration coefficient	0.155	6.72
Grain wt / panicle × plant height	0.049	2.13
Grain wt / panicle × LAI	-0.036	1.56
RPP_{gr} ×migration coefficient	-0.122	5.29
RPP_{gr} ×plant height	-0.031	1.34
RPP_{gr} × LAI	0.023	1.00
Migration coefficient × plant height	0.054	2.34
Migration coefficient × LAI	-0.039	1.69
Plant height × LAI	-0.033	1.43
R^2	0.999	99.99
Residual	0.001	0.01
Total	1.000	100.0

References

Abdel- Gawad, A.A., K.A. El-Showay, S.A. Saleh and M.A. Ahmed, 1987. Partition and migration of dry matter in newly cultivated wheat variety. Egypt. J. Agron., 12: 1-16.

Ahmed, A.G., N.M. Zaki and M.S. Hassanein, 2007. Response of grain sorghum to different nitrogen sources.Res.J.of Agric. and Biol.Sci., 3: 1002-1008.

Ahmed, M.A., M.A. Al-Kordy, Magda A.F. Shalaby and M.S. Hassanein, 2011. Genetic analysis of energy production in white maize hybrids grown in newly cultivated sandy land. J.of Appl. Sci. Res., 5: 104-114.

A.O.C.S., 1998. Official. Methods of Analysis of the Association of Official Chemists, Washington. D.C., USA.

Bremner, P.M. and M.A. Taha, 1966. Studies in potato agronomy. 1- The effect of variety, seed size and spacing on growth, development, and yield. J.Agric. Sci., 66: 241-252.

Clark, R.B., S.K. Zeto, V.C. Baligar and K.D. Ritchey, 1997. Growth triats and mineral concentrations of maize hybrids grown in unlimed and limed acid soil. J.of plant Nut., 20: 1773-1795.

El-Gazzar, M.M., 2003. Evaluation of six sorghum cultivars in photosynthate partition and migration, growth and its components in newly cultivated land. Egypt. J.Appl. Sci., 18: 232-246.

Dubois, M., K. Gilles, J. Hamilton, R. Robers and F. Smith, 1956. Colorimetric method for determination of sugar and related substances. Anal. Chem., 28: 350.

El-Hattab, A.H., S.A. Shaaban, D.M. El-Harriri, El-Gazzar and A.G. Ahmed, 2000. Growth characters, grain yield and quality of two sorghum cultivars as affected by skipping irrigation. Egypt. J. Appl. Sci., 15(11): 168-171.

Fisher, R.A., J. Aguilar and D.R. Long, 1977. Path analysis sink size in high yielding dwarf wheat, yield response to grain number. Aust. J.of Agric. Res., 28: 165.

Hanson, W.D., R.C. Leffel and R.W. Howell, 1960. Genetic analysis of energy production in soybean. Crop Sci., 1: 121.

Hassanein, M.S., Amal. G. Ahmed and Nabila M. Zaki, 2010. Growth and productivity of some sorghum cultivars under saline soil condition. J. of Appl. Sci. Res., 6: 1603-1611.

Mc Graw, R.L., 1977. Yield dynamics of florunner peanut (*Arachis hypogaea* l.) M.Sc. Thesis, Florida.

Neter, J. and W. Wasswrman, 1974. Applied linear statistical methods. Richard, D.Irwin,Inc., Home-Wood, Illionois, 60340.

Penning De Vries. F.W.T., A.H.M. Brunsting and H.H. Van Lear, 1974. Products requirements and efficiency of biosynthesis a quantitative approach. J. Tneor. Biol., 45: 339.

Pucridge, 1971. Photosynthesis of wheat under field conditions. III-Seasonal trends in carbon dioxide uptake of crop communities. Aust. J. Agric. Res., 22: 1.

Saleh, S.A., M.A. Ahmed, M.A. Al-Kordy and Magda A.F. Shalaby, 2011. Genetic analysis of energy production in yellow maize hybrids cultivated in newly cultivated sandy land. Aust.J. of Basic and Appl Sci., 5: 104-114.

Snedecor, G.W. and G.W. Cochran, 1982. Statical Methods, 7 th, Ed. Oxford and I.B.H. Publishing Iowa State Univ., Press, Iowa.USA.

Selim, M.M., 1995. Evaluation of some grain sorghum genotypes grown under different plant densities and level of nitrogen fertilization. Egypt. J.Agron., 20: 83-97.

Vidovic, J. and V. Pokorny, 1973. The effect of different sowing densities and nutrient level on LAI, production and distribution of dry matter in maize. Glanta,15: 374.

Volaskii, N.I., E.E. Bystrykli and E.K. Nikolaeva, 1978. Photosynthetic activity of the upper leaf of the wheat varieties with different productivity. S.Kh. Biol., 13: 703.

Wright, S., 1934. The methods of path Coefficient. Ann. Math. State, 5: 161.