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Growth and Yield of Soybean Intercropped with Grain Sorghum

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Abstract: Two grain sorghum (*Sorghum bicolor* L. Moench) varieties, semi-dwarf *viz*. Dorado and a tall Giza-15 were intercropped with soybean (*Glycine max* L. Merrill) variety Giza -82 at a 2:2 intercropping pattern. Grain sorghum varieties were planted with three planting densities (D1, D2 and D3) which represent 100, 150 and 200% of the recommended plant density, while soybean was planted at 210 $x10^3$ plants fed^{-1} under intercropping system (150% of the recommended density). Additional plots of soybean: solid I (the recommended planting) and solid II treatment (the comparative treatment) where soybean was planted at the intercropped plant density were applied. The results revealed that there were adverse effects on illumination along soybean plants due to intercropping. Soybean intensification under intercropping either with Dorado or Giza-15 varieties reduced the percentage of light intensity regardless of sorghum planting density over soybean canopy by 54.1 and 65.4%, respectively. While in the mid soybean canopy, the corresponding reduction percentages were 79 and 87.3 for Dorado and Giza-15 varieties, respectively. As grain sorghum plant density increased, the light intensity decreased at any position along the soybean canopy. The intercropped soybean suffered from partial shading resulting from the companion grain sorghum varieties which increased plant height, decreased pod-set and weight as well as the dry weight of different parts of soybean plant. Soybean seed yield per plant and per feddan were reduced due to intercropping. The degree of seed yield reduction depended on the variety and the density of the companion grain sorghum. The semi-dwarf variety Dorado seemed to be less competitive when intercropped with soybean than the tall variety Giza-15. The data indicated that cultivation soybean with 50%excess in plant density in 50% of the area under intercropping did not compensate the decrease of intercropped soybean productivity compared with the solid recommended plant density. It could be concluded that choosing the compatible varieties and the balanced densities of grain sorghum- soybean intercrops is very important for maximizing the productivity of unit area under intercropping.

Key words: Soybean · Intercropping · Sorghum · Light intensity growth · Yield

INTRODUCTION

Nowadays, the crisis of foodstuff shortage especially poultry and animal feeding commodities which are imported abroad have been exploded due to some economic problems. Intercropping of field crops is regarded as an essential practice when several economic field crops are competing for the same limited land area. Also, it is a common practice in small-scale farming systems in developing and sub-tropical countries [1, 2]. Intercropping offers farmers the opportunity to engage the nature's principle of diversity at their farms [3-5]. Several investigators [6-9] have emphasized that intercropping is the most effective tool which permits higher grain yields and greater land use efficiency per unit land area. Soybean has a wide range of compatibility with other crop species in intercropping systems such as maize [10], sesame [11], sunflower [12], and sweet corn [13]. Under the intercropping system, attention should be paid to the crops, which can grow with minimum competition and maximum profit [14]. When legume crops are grown as intercrop they suffer from biological stress due to shading from companion crops at different growth stages [15] and special attention in dealing with the biological stress when intercropping is practiced, short mungbean plants suffered much more from competition than the tall

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crop plants in a mixture leading to the reduction of photosynthetically active radiation (PAR) and in turn reducing the biological efficiencies of legume ability nutritional status [16]. The intercropped crops should be selected based on their resource use capability and competitive ability in time or space. Moreover, plant stand and planting geometry also influence resource use efficiency by crops in the mixture [17]. Furthermore, paired-row geometry of planting of the base crop is beneficial because more space for intercrops is created. Sometimes in replacement series of intercropping system, population density is enhanced compared to the pure stand of individual crops to achieve higher system productivity with greater leaf area index (LAI) [18]. Therefore, the combination of short and long duration crops or shallow and deep-rooted crops are preferred.

Grain sorghum (*Sorghum bicolor* L. Moench) is one of the major cereal crops in Egypt, as the cultivated grain sorghum area about 147.961 hectares produced about 727648 tons [19]. It has a remarkable ability to produce a crop under a biotic stress conditions, such as heat, drought and salinity. Seventy percent of cultivated areas concentrated in Upper Egypt. Also, the El-Fayoum province has a large cultivated area due to soil problems such as salt, drought and low fertility in addition to heat stress which prevent the cultivation of other crops. In addition, it is a double purpose crop; the vegetative parts are used for animal feeding in the summer season when green forage crops are not quite available. The total production of grain sorghum in Egypt is less than the needs of the local consumption [20].

Soybean (*Glycine max* L. Merrill)is an important leguminous crop for its great nutritional value. In Egypt, soybean as being a summer crop could compete with other summer field crops for the limited area of the cultivated land. One of the proposed solutions for such problem is intercropping [21]. However it was emphasized that when soybean is intercropped with grain sorghum, soybean yield may be reduced [22, 23].When soybean was intercropped with maize or sorghum at different plant densities, the reduction in the soybean seed yield was variable [24, 25]. It is evident that intercropping soybean with crops with greater canopy decreased the growth and the yield of soybean mainly due to reduction of solar radiation intercepted by soybean [26]. Thus, a more uniform distribution of solar radiation within the canopy keeps the upper leaves radiation saturated and the lower leaves radiation starved thus planting patterns were used to influence the distribution of the radiation in the canopy as **wen** as the incident radiation intercepted by a crop [24]. The aim of this study is to throw some light on the effect of variety and density of grain sorghum plants on the intercropped soybean growth and yield.

MATERIALS AND METHODS

Two field experiments were conducted during the two successive summer seasons 2021 and 2022 in a private farm at Aiat Province, Giza Governorate. The experiments aimed to study the effect of intercropping two grain sorghum varieties *i.e.,* semi-dwarf; Dorado and tall Giza-15 with soybean variety Giza-82 in alternating 2 ridges (2 and 2 pattern). The grain sorghum varieties were planted at a distance of 15 cm for Dorado and at 20 cm for Giza-15 variety with 2, 3 and 4 plants hill^{-1}, whereas soybean was sown on both sides of the ridges at distance of 5 cm. Additional plots of solid I (the recommended planting) and solid II treatment (the comparative treatment) where soybean was planted as in intercropping on both sides of the ridge were applied. Thus grain sorghum varieties were planted with three planting densities (D1, D2 and D3) which represent 100, 150 and 200% of the recommended plant density, while soybean was planted at 210 plants fed^{-1} under intercropping system (150% of the recommended density). Additional plots of soybean: solid I (the recommended planting) and solid II treatment (he comparative treatment) where soybean was planted at the intercropped plant density. The cultivated area of sorghum and soybean was 50% under 2:2 intercropping pattern respectively. The experimental design was split-plot with four replicates where grain sorghum varieties were arranged in the main plots and the planting densities in the sub-plots. The soil was ploughed twice, ridged, and divided to experimental plots; a border of 1m was left between each two experimental plots to avoid shading effect soybean seeds were grown in the assigned ridges on May 29th and June 3rd in the 2021 and 2022 seasons, respectively by the Hearty (wetted method) where the seeds were sown in hills 10 cm apart on both sides of the ridge. After the germination was completed-Soybean seedlings were thinned to obtain the required density. The assigned ridges for grain sorghum were left, two weeks later grain sorghum varieties were sown by the Afeer (dried method) in hills 20 cm apart and after complete germination, grain sorghum seedlings were thinned at 2, 3 and 4 plants per hill to obtain the required density (D1, D2 and D3) and under the solid I treatment where thinning was applied in 2 plants per hill. At grain sorghum heading stage (after 65 days from sowing), the light intensity was measured over, mid and under soybean canopy by using Lux Meter according to [27, 28]. The light interception was measured for the solid and intercropping systems by using luxmeter in luxes according to then the units were converted to energy units where 1 lux = 0.000000146 watt/centimeter^2 (at 555 nm). Ten soybean plants were taken from each experimental unit to determine the growth characters of soybean, *i.e.* plant height and number of pods plant^{-1}. The plants were then separated into pods, stems+ leaves dried and weighed to obtain pod weight per plant; dry weight of stems + leaves as well as the total dry weight per plant. At harvest time seed yield per plant and per feddan were determined.

The experimental design was split-plot design with four replicates where the main plots were devoted for the grain sorghum varieties while the possible combinations of the cropping patterns and the different plant densities were assigned to the sub-plots.

Statistical Analysis: The data were subjected to the proper statistical analysis according to [29] since the data in both seasons took similar trends, Bartlett's test was applied and the combined analysis of the data was done. For means comparison Duncan's multiple range test was applied at 5% level according to [30].

RESULTS AND DISCUSSION

A) Light intensity Measurements: Data presented in Table 1 and Fig. 1 show that intercropping grain sorghum with soybean led to a significant reduction in light intensity over, in the mid and under soybean as compared with the solid soybean culture (129166.925 lm/m^2). The degree of light intensity reduction varied according to the variety and density of the companion grain sorghum on light intensity over, in the mid, and under soybean as a percent of the full sunlight either in intercropped or solid canopies (Table 1). It is clear from this table that

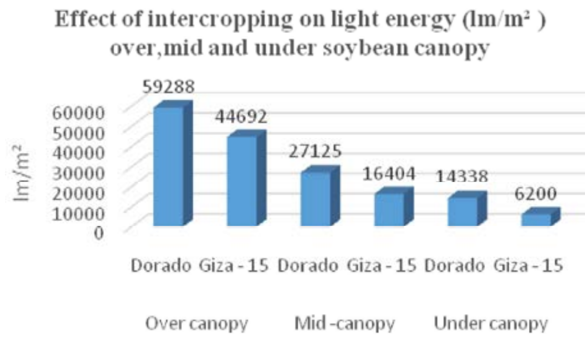

Fig. 1: Effect of sorghum companion variety on light energy over, in the mid and under intercropped soybean canopy (lm/m^2)

intercropping soybean with Dorado and Giza-15 varieties reduced the percentage of light intensity regardless of sorghum planting density over soybean canopy by 54.1 and 65.4%, respectively (Fig. 2). While in the mid soybean canopy, the corresponding reduction percentages were 79 and 87.3 for Dorado and Giza-15 varieties, respectively. Meanwhile, the most severe reduction in the light intensity percent was found under soybean canopy which reached 88.9 and 95.2 % of the full sun-light for the varieties Dorado and Giza-15, respectively. From the same table it could be noticed also that as grain sorghum plant density increased, the light intensity decreased at any position along soybean canopy. Generally, these results show that the semi-dwarf grain sorghum (Dorado) is less aggressive to soybean for light than the taller one (Giza-15) since the later had the highest values of partial shading effect along the intercropped soybean.

B) Effect of Grain Sorghum Variety, and Planting Density on Soybean Growth Characters:

Plant height and number of pods per plant: Data presented in Table (2) show that there are significant differences between solid and intercropped soybean in

Table 1: Effect of sorghum companion variety and planting density on light energy reduction over, in the mid and under intercropped soybean as a percent of the full sunlight

Light intensity measurement	Sorghum density / Sorghum variety	Intercropped soybean D1	D2	D3	Mean	Soybean solid cultures Solid I	Solid 11
Over canopy	Dorado	58.8b	46.7c	32.3d	45.9A	100.0a	100.0a
	Giza-15	43.9c	35.3d	24.5e	34.6B		
In the mid-canopy	Dorado	26.6d	20.4ef	16.1fg	21.0A	34.9a	49.3b
	Giza-15	19.8ef	12.4g	6.0h	12.7B		
Under canopy	Dorado	16.3c	10.3d	6.8e	11.1A	23.9a	16.4b
	Giza-5	7.2e	4.3f	2.8e	4.8B		

Table 2: Effect or grain sorghum variety, plant density and cropping pattern on soybean growthcharacters at 65 days form sowing

Character	Sorghum density Sorghum variety	Intercropped soybean D1	D2	D3	Soybean solid cultures Solid I	Solid 11
Plant height (cm)	Dorado	65.0f	73.1de	80.4c	71.5de	75.5d
	Giza-15	72.8de	87.6b	92.2a		
No. of pods Plant^{-1}	Dorado	23.6c	19.0d	12.6f	34.4a	26.9b
	Giza-15	14.9ef	11.3fg	8.7g		
Dry weight of leaves + stems (g plant^{-1})	Dorado	6.0cd	5.2cd	4.3d	12.3a	9.9b
	Giza-15	4.0d	5.6cd	4.3d		
Dry weight of pods (g plant^{-1})	Dorado	12.2b	8.8c	7.1d	14.3a	12.6b
	Giza-15	6.5d	6.9d	5.5d		
Total dry weight (g plant^{-1})	Dorado	17.9c	14.0d	11.2e	26.6a	22.6b
	Giza-15	10.5e	12.5de	9.8e		

Table 3: Effect of sorghum variety and planting density on relative seed yield

Character	Sorghum density Sorghum variety	Intercropped soybean D1	D2	D3	Soybean solid cultures Solid I	Solid 11
Seed yield plant^{-1} (g)	Dorado	7.1c	5.1d	4.0f	16.2a	8.6b
	Giza-15	5.5d	4.6e	2.9g		
Relative seed yield plant^{-1} (relative to SolidII)	Dorado	0.7	0.5	0.4	1.6	1.0
	Giza-15	0.5	0.5	0.3		
Seed yield fed^{-1} (kg)	Dorado	643.3b	489.8d	312.9e	1011.2a	989.5a
	Giza-15	459.0c	285.8e	193.9f		

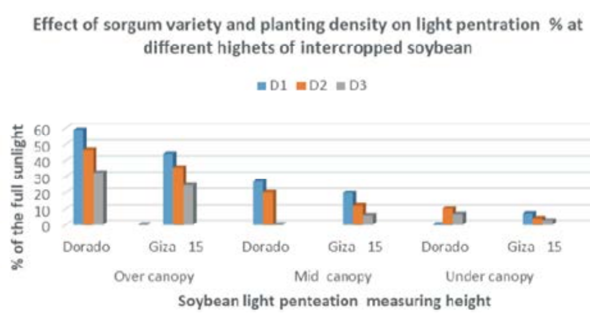

Fig. 2: Effect of sorghum companion variety on Light energy reduction over, in the mid and under intercropped soybean as a percent of the full sunlight

plant height after 65 days from sowing. In general, intercropped soybean plants tended to be taller than those in solid cultures. Soybean plants when intercropped with Giza-15 variety, gave taller than those intercropped with the other two semi-dwarf grain sorghum (Dorado). In addition, increasing the density of grain sorghum plants under intercropping pattern from 100 to 150 or even 200% resulted in significant increases in soybean plant height. It could be also noticed that the tallest soybean plants were obtained when they were intercropped with Giza-15 grain sorghum plants at density rate of 150 or 200%.

Soybean Dry Weight: Data presented in Table (2) show that the dry weight of different parts of soybean plant was reduced under intercropping conditions as compared with the solid patterns (solid I and solid 11). There are no varietal differences in the effect of grain sorghum on the dry weight of vegetative parts of soybean. The pod dry weight and the total dry weight per soybean plant were significantly heavier when it was intercropped with Dorado as compared to Giza-15. Moreover, increasing grain sorghum plant density significantly decreased the pod dry weight and the total dry weight of soybean plants. It could be also noticed that there is a strong relationship between the reduction in growth of different plant parts of soybean and the reduction in light intensity due to intercropping.

C) Effect of Grain Sorghum Variety, and Plant Density on Soybean Productivity:

Seed Yield per Plant: The data presented in Table (3) reveal that seed yield per plant was significantly affected by the companion grain sorghum variety and the degree of plant density as well as the cropping pattern. In general, under intercropping, soybean seed yield per plant was reduced as compared to the solid recommended practice (solid I) or the comparative treatment where the same soybean density was applied (solid II). The degree

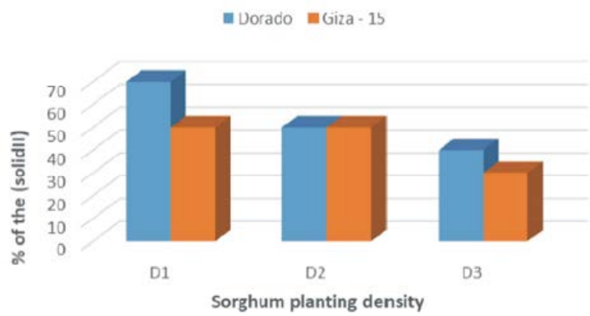

Fig. 3: Effect of sorghum variety and planting density on relative seed yield plant^{-1} of intercropped soybean

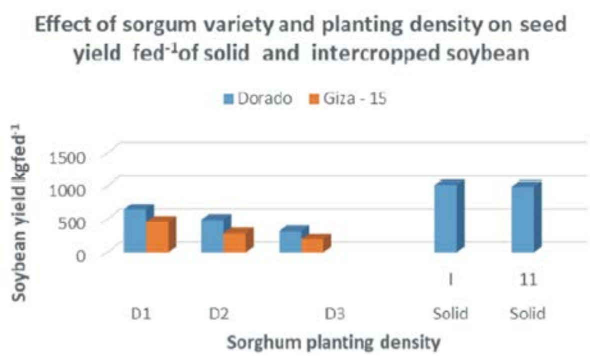

Fig. 4: Effect of sorghum variety and planting density on seed yield fed^{-1}

of seed yield reduction per plant of intercropped soybean depended upon the companion variety and density of grain sorghum (Table 3). The semi-dwarf grain sorghum variety (Dorado) induced less reduction in seed yield of intercropped soybean than did the tall one Giza-15 (Fig. 3). It is obvious also from the table that when sorghum plant density was increased, soybean seed yield per plant tended to decrease.

Soybean Seed Yield Fed^{-1}: The data presented in Table 3 and Fig. 4 shows that the yield of soybean under either the solid recommended practice (solid I) or the comparative treatment (solid 11), significantly surpassed the intercropped soybean. Such superiority is expected due to intercropping and the difference in the allocated sowing area, where only 50% of the area is occupied by soybean under intercropping, but 100% of the area is occupied by soybean under solid culture. The data indicated that in spite of the intensification of growing soybean with 150% of the recommended planting density for sole cropping in 50% of the area under intercropping, it did not compensate the decrease in intercropped soybean productivity. The companion variety of grain sorghum to soybean adversely affected seed yield of soybean fed^{-1}, Dorado variety had significantly the least effect than the other tall variety on the yield of intercropped soybean. Also, when grain sorghum plant density was increased, the seed yield of soybean per feddan was decreased. The greatest reduction in seed yield was found when grain sorghum was planted at D3 planting density for both varieties. It could be concluded that choosing the compatible varieties and the balanced densities of grain sorghum soybean intercrops is very important for maximizing the productivity of unit area under intercropping.

DISCUSSION

It could be noticed also that as grain sorghum plant density increased, the light intensity decreased at any position along soybean canopy. Generally, these results show that the semi-dwarf grain sorghum (Dorado) is less competitive to soybean for light than the taller one (Giza-15) since the later had the highest values of partial shading effect along the intercropped soybean. Under intercropping circumstances, soybean plants compete with grain sorghum plants for light thus, leading to the elongation in soybean internodes and consequently taller soybean plants were found. Moreover, the reduced light intensity along soybean canopy especially in the mid and under soybean canopies due to grain sorghum shading resulted in the reduction of pod set per soybean plant. In this respect, Abd El Lateef *et al*. [8] reported that the reduction in light penetration inside legume canopies was expected, and the biological stress resulted from the companion dominant crop was minimized to reach similar values of light energy flux density under the same planting density in solid cultures of legumes(Mungbean or Cowpea).

The reduction in soybean due to the increase of grain sorghum plant density significantly decreased the pod dry weight and the total dry weight of soybean plants. It could be also noticed that there is a strong relationship between the reduction in growth of different plant parts of soybean and the reduction in light intensity due to intercropping. Abd El Lateef *et al.* [31] attributed such reduction to the partial shading which reduced the photosynthetically active radiation (PAR)over the intercropped soybean which in turn reduced the photosynthesis in soybean leaves. In this respect, several investigators attributed the variability of legume tolerance to shading effects to the difference in the foliage architecture of the intercropped legumes [32-36].

Soybean seed yield reduction under intercropping pattern was expected and documented. Such reduction was attributed to the decrease of photosynthesis accumulated in the leaves due to shading resulted from the tall companion crop which in turn decreased the intensity of photosynthesis and slowed down the movements of metabolites from the soybean, leaves (source) to the developing pods (sink). Several workers came to a similar conclusion [33, 37, 38]. Metwally *et al*. [39] reported that Intercropping produced taller soybean plants, possessing lesser numbers of fruiting branches, pods, and seeds and seed yields. Recommended density (Solid 1) recorded significantly greater values of soybean yield components and seed yield plant^{-1} than dense density (Solid 2). Soybean seed yield per feddan decreased significantly by intercropping with maize by 47% and 49% compared to Solid 1 and Solid 2, respectively.

The companion grain sorghum variety to soybean adversely affected seed yield of soybean per feddan where Dorado variety had significantly the least effect than the other tall variety. At the same time, the semi-dwarf variety induced much fewer adverse effects on soybean seed yield per feddan than did the tall one. Also, when grain sorghum plant density was increased; the seed yield of soybean per feddan was decreased. The greatest reduction in seed yield was found when grain sorghum was planted at D3 density l for both varieties; other investigators came to a similar conclusion [40, 41] reported that in an intercropping system with base crops like maize, cotton, sugarcane the crops with various durations and different growth habits with peak demand for nutrients are chosen to minimize competition among the species.

CONCLUSION

This study pointed out to the choice of a proper intercropping components with the balanced planting density and appropriate management practices are major concerns to obtain advantages from the sorghum - soybean intercropping system.

REFERENCES

1. Glaze-Corcoran, S., Hashemi M., Sadeghpour A., Jahanzad E., Afshar R.K., Liu X.and Herbert, S.J., 2020. Understanding intercropping to improve agricultural resiliency and environmental sustainability. Advances in Agronomy, 162: 199-256.
2. Hong, Y., Heerink N.and W. van der Werf, 2020. Farm size and smallholders' use of intercropping in Northwest China. Land Use Policy, 99: 105004.
3. Shevchenko, V.A., A.M. Soloviev and N.P. Popova, 2021. Eligibility criteria for joint ensilage of maize and yellow lupine on poorly productive lands of the Upper Volga region. Caspian Journal of Environmental Sciences, 19: 745-751.
4. Rakhimova, O.V., V.K. Khramoy, T.D. Sikharulidze and I.N. Yudina, 2021. Influence of nitrogen fertilizers on protein productivity of vetch-wheat grain under different water supply conditions. Caspian Journal of Environmental Sciences, 19: 951-954.
5. Amraei, B., 2022. Effects of planting date and plant density on yield and some physiological characteristics of single cross 550 hybrid maize as a second crop. Caspian Journal of Environmental Sciences, 20: 683- 691.
6. Dantata, I.J., 2014. Effect of legume-based intercropping on crop yield: A review. Asian J. Agric. Food Sci., 2: 507-522.
7. Eskandari, H., 2012. Yield and quality of forage produced in intercropping of maize (*Zea mays*) with cowpea (*Vigna sinensis*) and mungbean (*Vigna radiate*) as double cropped. J. Basic Applied Sci. Res., 2: 93-97
8. Abd El-Lateef, E.M., M. Hozyn and M.H. Mohamed, 2010. Effect of maize-mungbean intercropping on light interception, yield and land use efficiency. Bull. NRC, 35: 169-184.
9. Abd El-Lateef, E.M., M.S. Abd El-Salam, S.F. El-Habbasha and M.A. Ahmed, 2015. Effect of maize-cowpea intercropping on light interception, yield and land use efficiency. Int. J. Chem Tech Res., 8: 556-564.
10. Morgado, L.B. and R.W. Willey, 2003. Effects of plant population and nitrogen fertilizer on yield and efficiency of maize-bean intercropping. Pesq. Agropec. Bras., 38: 1257-1264.
11. Bhatti, I., H.R. Ahmad, A. Jabbar, M.S. Nazir and T. Mahmood, 2006. Competitive behavior of component crops in different sesame-legume intercropping systems. Int. J. Agric. Biol., 8: 165-167.
12. Kandhro, M.N., S.D. Tunio, H.R. Memon and M.A. Ansari, 2007. Growth and yield of sunflower under influence of mungbean intercropping. Pak. J. Eng. Vet. Sci., 23: 9-13.
13. Sarlak, S., M. Aghaalikhani and B. Zand, 2008. Effect of plant density and mixing ratio on crop yield in sweet corn/mungbean intercropping. Pak. J. Biol. Sci., 11: 2128-2133.

14. Abdel Motagally, F., and A. Metwally. 2014. Maximizing productivity by intercropping onion on sugar beet. Asian Journal of Crop Science, 6(3): 226-35. doi: 10.3923/ajcs.2014.226.235.
15. Abd El-Lateef, E.M., B.A. Bakry, M.S. Abd El-Salam and T.A. Elewa, 2015. Mungbean (*Vigna radiata* L. Wilczek) varietal tolerance to biological stress. Int. J. Chem. Tech. Res., 8: 477-487.
16. Choromanska, U., 1995. Corn yield response to rotation effect, N fertilizer application and row position in a strip intercropping system. M.Sc. Thesis, Iowa State University, USA.
17. Maitra, S., T. Shankar and P. Banerjee, 2020. Potential and advantages of maize-legume intercropping system. In Maize - Production and Use; Hossain, A., Ed.; Intechopen: London, UK.
18. Wang, X., X. Wu, G. Ding, F. Yang, T. Yong, X. Wang and W. Yang, 2020. Analysis of Grain Yield Differences among Soybean Cultivars under Maize–Soybean Intercropping. Agronomy, 10: 110.
19. FAO, 2017. http: //appsl. Fao.Org/servlet/Xte Servlet.jrun
20. Abdel-Motagally, 2010. Evaluation of water use efficiency under different water Regime in grain sorghum (*Sorghum bicolor* L. Moench). World J. Agric. Sci., 6(5): 499-505.
21. Sayed Galal, Jr. and A.A. Metwally, 1982. The variability in intercropping tolerance of 18 soybean varieties when grown with a newly developed corn stock (Cairo 1). Res. Bull. No. 2101: 1-15. Ain Shams Univ. Agric. Cairo, Egypt.
22. Ashour, N.I., M.M. Selim, E.M. Abd EI-Lateef and T.G. Behairy, 1992. Effect of variety, cropping pattern and plant density on growth and yield of grain sorghum-soybean intercrops. 1. Grain sorghum. Bull. NRC., Egypt 1 Accepted.
23. E.M. Abd EI-Lateef, 1993. Soybean Varietal Tolerance to Intercropping with Semi-Dwarf Grain Sorghum. Egypt. J. Physiol. Sci., 17(2): 287-295.
24. Abd El-Lateef, E.M., 1988. Effect of some cultural practices on the intercropping of maize and soybean production. Ph.D. Thesis, Fac. Agric., Cairo Univ., Egypt.
25. Saberi A.R., 2018. Comparison of Intercropped Sorghum- Soybean Compared to its Sole Cropping. Biomed J. Sci. & Tech. Res., 2(1). BJSTR.MS. ID.000701. DOI: 10.26717/BJSTR.2018.02.000701
26. Pelech, E.A., B.C.S. Alexander and C.J. Bernacc, 2021. Photosynthesis, yield, energy balance, and water-use of intercropped maize and soybean. Plant Direct published by American Society of Plant Biologists and the Society for Experimental Biology and John Wiley & Sons Ltd., pp: 1-14.
27. Milthorpe, F.L. and J. Moorby, 1979. An Introduction to Crop Physiology. Cambridge International Student, Edition, 2nd Ed., London.
28. Pearce, R.B., R.H. Brown and R.E. Blaser, 1996. Relationship between leaf area index, light interception and net photosynthesis in orchard grass. Crop Sci., 5: 553-556.
29. Steel, R.G.D. and J.H. Torrie, 1980. Principles and Procedures of Statistics. A Biometrical Approach. 2nd edition. McGraw Hill Book Company, New York.
30. Duncan, D.B., 1955. Multiple ranges and multiple F test. Biometrics, 11: 1-41.
31. Abd El Lateef, E.M., A.E.M. Eata, Asal M. Wali and M.S. Abd El-Salam, 2020. Evaluation of mungbean (*Vigna radiata* L. Wilczek) as green pod and seed crop under different cropping systems in Egypt. Asian J. Crop Sci., 12: 115-123.
32. Naveed, A., M.H. Mirza, A. Akhtar and R. Muhammad, 2000. Intercropping Maize with Cowpea under rained conditions. Pakistan J. Biol. Sci., 3(4): 647-648.
33. Tsub, M. and S. Walker, 2002. A model of radiation interception and use by maize - bean intercrop canopy. Agricultural and Forest Meteorology, 3(110): 203-215.
34. Awal, M.A., H. Koshi and T. Ikeda, 2006. Radiation interception and use by a maize /peanut intercrop canopy. Agricultural and Forest Meteorology 1-2(139): 74-83.
35. Asmat, U., M.B. Ashraf, Z.A. Gurmani and M. Imran, 2007. Studies on planting patterns of maize (*Zea mays* L) facilitating legumes intercropping. J. Agric. Res., 45(2): 112-118.
36. Ghosh, P.K., M.C. Mannab, K.K. Bandyopadhyayb, A.K. Ajayb, R.H. Tripathib, K.M. Wanjarib, A.K. Hatib, C.L. Misrab and R.A. Subba, 2006. Interspecific interaction and nutrient use in soybean/sorghum intercropping system. Agron. J., 98: 1097-1108.
37. Shen, L., 1984. Yield responses of corn and soybean strip intercropping in different row directions, M. Sc. thesis, Iow State Univ. Ames. (Cited after Whigham, D.K. in world soybean Res. Conf. Proceed. 1025-1031).
38. Subramanian, V.B. and D.G. Rao, 1988. Intercropping effect on yield components of dry land sorghum, pigeon pea and mungbean. Trop. Agric., 65(2): 145.

39. Metwally, A.A., M.M. Shafik, El-M.A. El-Metwally and S.A. Safina, 2003. Tolerance of some soybean varieties to intercropping. Proc. 10^{th} Conf. Agron., Suez Canal Univ., Fac. Environ. Sci., EL-Arish, Egypt, pp: 279-293.
40. Manasa, P., S. Maitra and M.D. Reddy, 2018. Effect of summer maize-legume intercropping system on growth, productivity and competitive ability of crops. Int. J. Manag. Technol. Eng., 8: 2871-2875.
41. Maitra, S., S.K. Samui, D.K. Roy and A.K. Mondal, 2001. Effect of cotton based intercropping system under rain fed conditions in Sundarban region of West Bengal. Indian Agric., 45: 157-162.