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Productivity Enhancement of Soybean Through Appropriate Planting Geometry and Canopy Manipulation in Maize-soybean Intercropping to Mitigate Changing Climate

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ABSTRACT

Soybean remains in stress due to shading effect of maize in maize soybean intercropping system especially during autumn crop cultivation. Appropriate planting geometry with canopy manipulation of maize would pave the way to improve productivity of soybean in maize soybean intercropping, thereby mitigating changing climate. Considering the aforementioned facts, study was conducted in the Agronomic Experimental Area, University of Agriculture Faisalabad in Autumn 2020-21; repeated

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in Autumn 2021-22. In the experiment, three planting geometries i.e. PG1: 60 cm apart double row bed plantation, PG2: 75 cm apart single row ridge plantation and PG3: 75 cm apart double row ridge plantation and four canopy manipulation techniques of maize i.e. CM1: No leaf removal and no detasseling of maize, CM2: Removal of 2 top leaves of maize, CM3: Detasseling of maize and CM4: Removal of 2 top leaves and detasseling of maize were implemented following RCBD in split plot arrangement under three replications having 3 m x 7 m gross plot size. The recorded data was statistically computed using Fisher's analysis of variance procedures, and the means of the treatments were compared using the Least Significant Difference (LSD) test at the 5% probability level. Results revealed that during both study years, most of the yield and growth-related metrics of soybean were significantly influenced by planting geometry (PG) and canopy manipulation (CM) of maize in maize-soybean intercropping, its maximum stem diameter (0.42 cm and 0.41 cm), pods per plant (44.33 and 41.66), seed yield (1.01 t ha^{-1} and 0.99 t ha^{-1}), biological yield (3.40 t ha^{-1} and 3.33 t ha^{-1}), seed protein contents (38.69% and 38.09%), CGR and NAR were observed with the treatment PG3CM4. However minimum values of all above mentioned soybean parameters were observed with treatment PG2CM1. Overall, during both the years (Autumn 2020-2021 and Autumn 2021-22), maximum BCR (1.96 and 1.89 respectively) values were also recorded with PG3CM4. It was concluded that 75 cm apart double row ridge plantation of maize (intercropped with soybean) with removal of 2 top leaves and detasseling is a feasible and economical strategy for soybean to attract the farming community of maize belt.

Key words: Canopy manipulation, Intercropping, Maize Soybean, Planting geometries,

INTRODUCTION

Soybean cultivation has been followed across the world both in sole and in intercropping, including countries in Asia, America and Africa (Yang et al., 2014). Intercropping systems have been widely used around the world because of their ability to improve land-use efficiency radiation use efficiency (RUE) (Yang et al., 2015). It can be predicted that maize soybean intercropping will increase the net profit and BCR which ultimately be very helpful to control the demand of oilseeds in Pakistan (Ahmad et al., 2016). In different regions of the world, especially Chinese farmers are growing soybean very successfully with maize through bed plantation (With the help of mechanized bed planters). Sichuan Agricultural University (SAU) has lot of its work on 2+4 bed planting geometry of maize and soybean. But in Pakistan, most of our farmers prefer ridge sowing. So, adjustment of soybean on ridges with maize again having a question mark.

In Pakistan, most of maize hybrids don't have erect type leaves, so shading effect for soybean on later stages is very common. To overcome this problem, there are different strategies which can be used; among those the most important approach is canopy manipulation of maize technique to reduce the shading effect of maize on soybean may work best. A maize farmer is getting 100 plus mounds grain yield, so soybean adjustment as intercrop should give promising results regarding quantity and quality

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for the maize farmer to attract them. Specific planting geometries of maize-soybean intercropping with appropriate crop manipulation can help us to overcome these drawbacks. Therefore, retaining in mind the aforementioned facts, a research trial was planned to assess the effectiveness of intercropping of maize soybean technique in various planting geometries and canopy manipulations of maize.

Intercropping mitigate complete crop failure, enhance the yield and microbial activity, increase area for production, elevate fertilizer use efficiency, improve nutritional value, enhance the water holding capacity and organic matter, reduce erosion, crust formation, pest and weed pressure. Intercropping improves the soil's properties including both the chemical and physical ones (Muneer et al., 2004; Khan et al., 2019). Modern studies all over the world suggested that polyculture is more profitable than monocultures (Mahmoudi et al., 2013; Saeed et al., 2014). In intercropping system, planting patterns and planting geometry also has an important effect on the production of both crops. In an intercropping system based on maize, maize planting geometries should be selected in such a way that its plant population as a main crop should be remained optimum as in sole cropping (Ehsanullah et al., 2011).

Being tall plant, the way that maize shades on short statured soybean has great hindrance for proper soybean growth, yield and production when used in intercropping. So, maize leave removal can be a viable strategy to reduce the negative effects of maize shadowing on soybean. When selective leaves from the maize canopy are removed, the transmission of radiation, mainly involved in photosynthesis is increased for the companion crop (Soybean). Resultantly significant improvement is observed in dry matter production of soybeans (Raza et al., 2019). Removal of top leaves increases yield and nutrient consumption in the blistering stage of maize plants. It provides a lighter environment and enhances nutrient uptake at the grain filling phase (Raza et al., 2020). Soybean leaves becomes smaller when they are grown under shade and ultimately results in a yield reduction of soybean. Shoot biomass, leaf area, leaf size, cell proliferation of soybean significantly reduced under shade (Wu et al., 2017). Soybeans are suppressed by shade in maize-soybean intercropping resulting in a loss of yield. An approach of maize leaf removal and using appropriate planting pattern with planting geometry can enhance the light environment for soybean that ultimately results in more soybean production (Banik et al., 2006; Raza et al., 2018).

It is commonly observation that almost all the crops experienced co growth phase for shading in intercropping (Valladares and Niinemets 2008). There are many adverse effects of shading, among them important one are leaf area development (Wu et al. 2017) and reduction in leaf photosynthates (Yang et al. 2017). Deficiency in sun light during grain filling period of maize, limits the photosynthetic rate of maize leaves. It is keenly observed that it is because of upper top structure which reduces the light interception by remarkable decline of 19% to lower sided leaves, which is mainly depends on the cultivar used (Karam et al., 2010). It is a common observation and proven fact in past, that middle portion of maize plant having leaves, are main contributors towards economic yield as these have more tendency to utilize more sunlight. (Kefu 1981; Liu et al., 2015).

Raza et al., (2019) conducted experiment for two years and concluded that shading conditions of maize leaves adversely affected the number of flowers and total pod

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numbers of soybeans under maize soybean relay-intercropping. Soybean canopies with improved PAR-transmittance showed a drop in lodging rate with height of soybean plant. High soybean leaf area index (LAI) is result of a better light atmosphere, allowing optimal leaf expansion, growth, better light harvesting and soybean leaf productivity. Since soybean LAI is linked to light intensity available, increase in LAI can be attributed to increased light of soybean canopy environment which drastically boosted the leaf area index (Raza et al., 2018).

MATERIALS AND METHODS

Research location and germplasm

This experiment was executed during Autumn 2020-21 and Autumn 2021-22 at Agronomic Research Area, University of Agriculture, Faisalabad (31.25° N, 73.09° E, altitude 184 m).

Soybean variety: NARC-16

Maize cultivar: YH-5427 (Semi-erect type)

Design: RCBD with split plot

Factor A: Planting Geometries (Main plots)

PG1 = 60 cm apart double row bed plantation

PG2 = 75 cm apart single row ridge plantation

PG3 = 75 cm apart double row ridge plantation

Factor B: Canopy Manipulations (Sub plots)

CM1: No leaf removal and no detasseling of maize

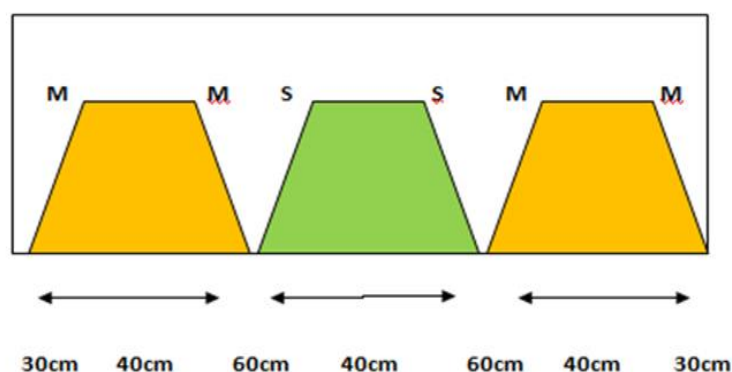
CM2: Removal of 2 top leaves of maize

CM3: Detasseling of maize

CM4: Removal of 2 top leaves and detasseling of maize

Planting geometries

In case of second experiment, regarding first factor i.e. planting geometries, preparation of 60 cm apart (PG1) and 40 cm wide beds were maintained in each plot (Size 3 m x 7 m). So, the distance from bed to bed was 60 cm. There were three beds in each plot. Two maize rows were maintained on the first bed and then on the third bed (Total 4 rows of maize in each plot). Plant to plant distance for maize was 17.5 cm. While, two soybean rows were maintained on the central bed. Plant to plant distance for soybean was 10 cm and two seeds per hill were used. So in this way, it was the combination of 4+2.



60 cm apart double rows maize-soybean bed plantation (4+2) *Raza et al., 2019*

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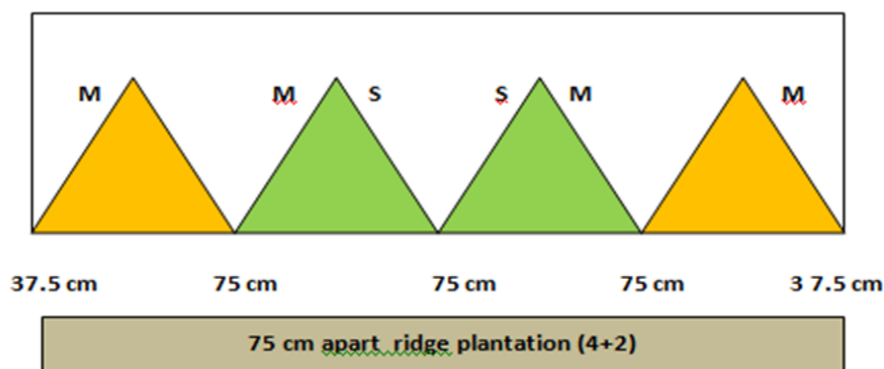
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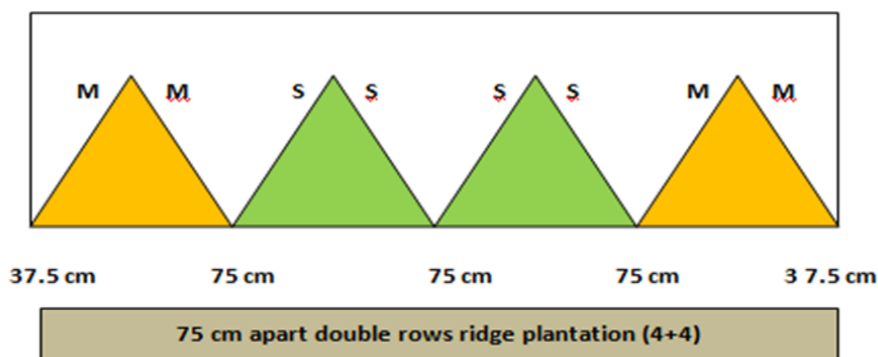
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For PG2 (75 cm apart single row ridge plantation) in each plot, 75 cm apart four ridges were maintained. On 1st and 2nd ridges, maize was planted on the left side and on the 3rd and 4th ridges; maize was planted on the right side of the ridges. In this way, space was created in between the 2nd and 3rd ridges for the plantation of two rows of soybean. Where, two seeds of soybean/hill were planted at (P x P) distance of 10 cm. Once again, it was the combination of 4+2.



In case of PG3 (75 cm apart double row ridge plantation), both sides of 1st and 4th ridges were used to grow maize plants (4 rows). However, both sides of 2nd and 3rd ridges were used to maintain four rows of soybean. For maize (P x P) distance was 17.5 cm while, for soybean 10 cm. In case of PG3, only one seed of soybean was placed per hill. So, it was the combination of 4+4 (Four rows of each maize and soybean in one plot).



The trial was included both broad and narrow leave crops therefore to control the weeds in it, pre-emergence weedicide, Stomp (Pendimethalin) + Dual Gold (S-metolachlor) and post-emergence weedicide, Atrazine was used. Regarding nutrients management, 250:125:125 kg ha⁻¹ NPK (recommended rates for main crop i.e. maize) was applied

by using Urea, DAP and Sulphate of potash. However, no extra fertilizer was applied for soybean. Total amount of P and K (DAP and SOP respectively) was applied at sowing whereas N was added from Urea in three splits that were at sowing, at 4-6 leaf stage and at flowering. For sowing, manual dibbling was carried out for both the crops in all the treatment.

RESULTS

Stem diameter

Data shows that during the two years of experimentation (Autumn 2020-21 and 2021-22), maximum stem diameter of soybean (0.42 cm and 0.42 cm respectively) were recorded with PG3CM4 (75 cm apart double row ridge plantation with removal of 2 top leaves and detasseling of maize) while minimum stem diameter of soybean (0.32 cm and 0.30 cm respectively) were recorded with PG2CM1 (75 cm apart single row ridge plantation with no leaf removal and detasseling of maize) (Table 1).

Number of pods per plant

Data shows that during Autumn 2020-21 and Autumn 2021-22, maximum pods per plant of soybean (44.33 and 41.66 respectively) were recorded with PG3CM4 (75 cm apart double row ridge plantation with removal of 2 top leaves and detasseling of maize) while minimum pods per plant of soybean (31.20 and 30.86 respectively) were recorded with PG2CM2 (75 cm apart single row ridge plantation with removal of 2 top leaves of maize) (Table 1).

1000-seed weight (g)

Data shows that during both the two seasons of experimentation, Autumn 2020-21 and Autumn 2021-22, maximum 1000-seed weights of soybean (118.67 g and 117.36 g respectively) were recorded with PG3CM4 (75 cm apart double row ridge plantation with removal of 2 top leaves and detasseling of maize) while minimum 1000-seed weights of soybean (100.26 g and 99.25 g respectively) were recorded with PG2CM1 (75 cm apart single row ridge plantation with no leaf removal and no detasseling of maize) (Table 1).

Seed yield (t ha⁻¹) and Biological yield (t ha⁻¹)

Data shows that during both the years (Autumn 2020-21 and Autumn 2021-22), maximum seed yield of soybean (1.01 t ha⁻¹ and 0.99 t ha⁻¹, respectively) were recorded with PG3CM4 (75 cm apart double row ridge plantation with removal of 2 top leaves and detasseling of maize) while minimum seed yield of soybean (0.40 t ha⁻¹ and 0.39 t ha⁻¹, respectively) were recorded with PG2CM1 (75 cm apart single row ridge plantation with no leaf removal and no detasseling of maize) (Table 1).

During both the years (Autumn 2020-21 and 2021-22), maximum biological yield of soybean (3.40 t ha⁻¹ and 3.33 t ha⁻¹, respectively) were recorded with PG3CM4 (75 cm apart double row ridge plantation with removal of 2 top leaves and detasseling of maize) while minimum biological yield of soybean (1.29 t ha⁻¹ and 1.28 t ha⁻¹, respectively) were recorded with PG2CM1 (75 cm apart single row ridge plantation with no leaf removal and no detasseling of maize) (Table 1).

Table 1. Impact of planting geometry and canopy manipulation of maize on soybean stem diameter, No. of pods per plant, 1000-seed wt. seed yield and biological yield during 2020-21 and 2021-22.

Year	Treatments	Stem diameter (cm)	No. of pods (Plant ⁻¹)	1000-seed weight (g)	Seed yield (t ha ⁻¹)	Biological yield (t ha ⁻¹)
Autumn 2020-2021	PG ₁ CM ₁	0.38 abc	35.93 abcd	106.53 abc	0.50 b	1.50 b
	PG ₁ CM ₂	0.38 abc	36.13 abcd	108.72 abc	0.51 b	1.51 b
	PG ₁ CM ₃	0.0.39 abc	34.76 bcd	106.45 bc	0.51 b	1.51 b
	PG ₁ CM ₄	0.38 abc	36.36 abcd	108.27 abc	0.52 b	1.57 b
	PG ₂ CM ₁	0.32 c	31.40 d	100.26 c	0.40 c	1.29 b
	PG ₂ CM ₂	0.34 abc	31.20 d	100.31 c	0.43 bc	1.31 b
	PG ₂ CM ₃	0.33 bc	29.66 d	100.66 c	0.43 bc	1.30 b
	PG ₂ CM ₄	0.33 bc	32.66 cd	101.28 c	0.44 bc	1.37 b
	PG ₃ CM ₁	0.41 ab	42.067 ab	116.34 ab	0.95 a	3.20 a
	PG ₃ CM ₂	0.41 abc	42.30 ab	117.29 ab	0.96 a	3.22 a
	PG ₃ CM ₃	0.42 a	41.66 abc	117.06 ab	0.98 a	3.21 a
	PG ₃ CM ₄	0.42 a	44.33 a	118.67 a	1.01 a	3.40 a
LSD		0.0492	9.2123	12.201	0.0954	0.4390
Autumn 2021-2022	PG ₁ CM ₁	0.36 bc	34.60 ab	106.14 ab	0.50 bc	1.49 b
	PG ₁ CM ₂	0.37 bc	33.66 ab	108.59 ab	0.50 bc	1.50 b
	PG ₁ CM ₃	0.36 bc	34.33 ab	105.98 ab	0.51 bc	1.50 b
	PG ₁ CM ₄	0.37 bc	35.53 ab	107.65 ab	0.51 b	1.56 b
	PG ₂ CM ₁	0.30 d	30.96 b	99.25 b	0.39 d	1.28 b
	PG ₂ CM ₂	0.32 d	30.86 b	99.92 b	0.41 cd	1.30 b
	PG ₂ CM ₃	0.31 d	31.00 b	99.97 b	0.42 bcd	1.30 b
	PG ₂ CM ₄	0.33 cd	31.33 b	99.86 b	0.43 bcd	1.36 b
	PG ₃ CM ₁	0.40 ab	38.40 ab	114.05 ab	0.95 a	3.16 a
	PG ₃ CM ₂	0.41 ab	38.96 ab	115.06 ab	0.95 a	3.17 a
	PG ₃ CM ₃	0.41 a	39.33 ab	116.86 a	0.97 a	3.20 a
	PG ₃ CM ₄	0.42 a	41.66 a	117.36 a	0.99 a	3.33 a
LSD		0.0445	7.7828	14.919	0.1049	0.3320

Leaf area index (LAI)

Leaf area index showed significant variation from 30 to 90 DAS in different planting methodologies. Highest values during both the years (Autumn 2020-21 and Autumn 2021-22) of LAI (0.34, 1.45, 4.02, 3.93, 2.30, 0.34 and 0.33, 1.36, 3.89, 2.29, 0.33) after 30, 45, 60, 75 and 90 DAS respectively were reported in treatment PG3CM4 where 75 cm apart double row ridge plantation of maize with 2 leaf removal with detessaling) was followed. However, lowest values of LAI (0.28, 1.35, 3.71, 2.20, 0.27 and 0.25, 1.28, 3.67, 2.14, 0.25) at 30, 45, 60, 75 and 90 days after sowing respectively were reported with treatment PG2CM1 where 75 cm apart single row ridge plantation of

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maize with no leaf removal and detessaling was followed (Fig. 1a and b).

Crop Growth Rate (CGR)

During both years (Autumn 2020-21 and Autumn 2021-22) Crop growth rate showed significant variation from 45 to 90 days after sowing. Highest CGR (0.38, 0.52, 0.99, 0.71 and 0.35, 0.5, 0.96, 0.7) at 45, 60, 75 and 90 DAS respectively) in treatment PG3CM4 where 75 cm apart double row ridge plantation of maize with 2 leaf removal with detessaling) was followed, while the lowest CGR (0.22, 0.39, 0.87, 0.58 and 0.21, 0.37, 0.85, 0.57) at 345,60, 75 and 90 DAS respectively) in treatment PG2CM1 where 75 cm apart single row ridge plantation of maize with no leaf removal and no detessaling was followed (Fig. 1c and d).

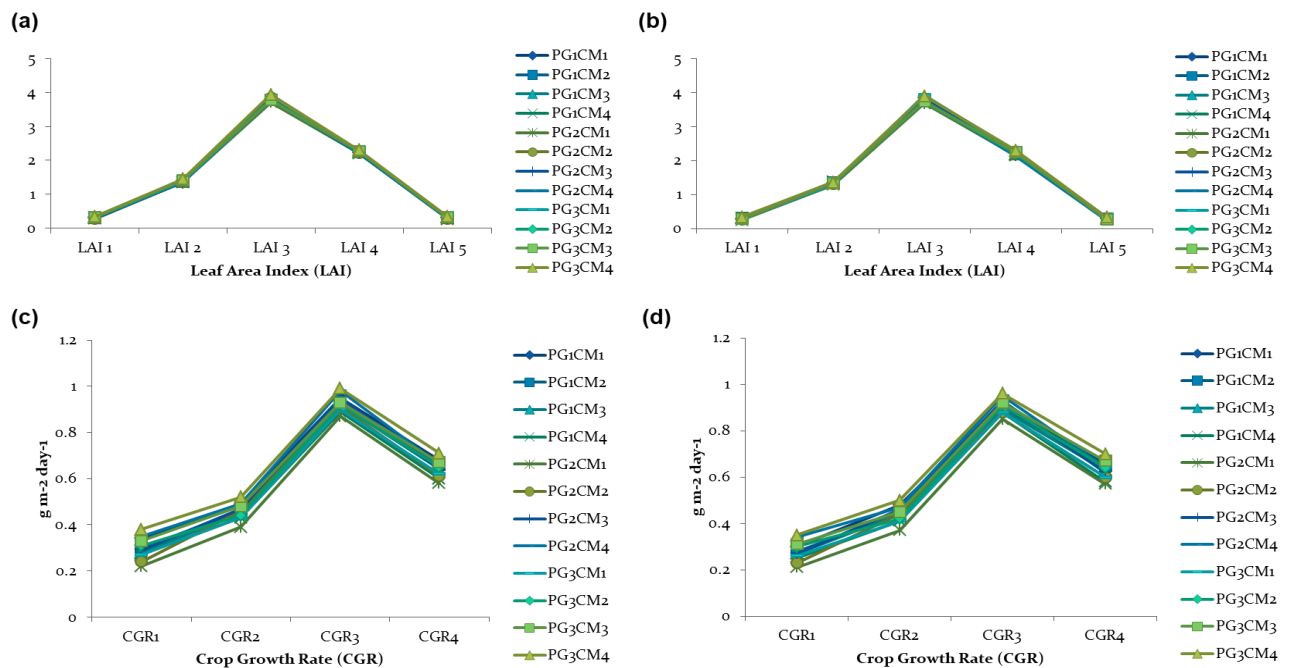


Fig. 1 (a). Impact of planting geometry and canopy manipulation of maize on LAI of soybean in maize soybean intercropping during autumn 2020-21. (b). Impact of planting geometry and canopy manipulation of maize on LAI of soybean in maize soybean intercropping during autumn 2021-22. (c). Impact of planting geometry and canopy manipulation of maize on CGR of soybean in maize soybean intercropping during autumn 2020-21. (d). Impact of planting geometry and canopy manipulation of maize on CGR of soybean in maize soybean intercropping during autumn 2021-22.

DISCUSSION

This study showed that different planting geometries and canopy manipulation of maize in maize soybean intercropping showed a beneficial influence on practically all agronomic characteristics of soybean during both the years (Autumn 2020-21 and Autumn 2021-22) of experimentation. Overall, growth and yield of soybean was observed better during first year (Autumn 2020-21) of experimentation, which is may

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be due to supporting weather conditions than second year (Autumn 2021-22) of experimentation.

Pods per plant are acknowledged as an important and noteworthy yield deciding part of soybean. Pod setting is exceptionally affected by the quick progression and advancement of leaves at bloom. The strong association between full pods per plant and seed yield demonstrated that pods per plant contribute more to soybean seed yield. The decrease in the pods per plant could be attributed to greater inter and intraspecific competition for growth resources, which could have resulted to a reduced number of effective branches. Similarly, Luiz and Robert, (2003) represented that increasing the soybean population in intercropping considerably reduced the quantity of pods per soybean plant. The results of this experiment were similar to those of Khan et al. (2015), who found a substantial difference in the pods per plant among soybean genotypes.

1000-seed weight contributes to final harvest of crop. It is directly related to pods per plant and seeds per pod. Weight variations were caused by the presence of different sorts of competition like photosynthetic activity, shading effect and less availability of growth resources and genetic character among the maize and soybean. Results were similar with Aziz et al. (2012) he reported that varied intercropping procedures had a substantial impact on 1000-seed weight of soybean in intercropping.

Seed yield was positively and strongly linked with leaf area, plant height, pods per plant, and 1000-seed weight. During the reproductive stage, environmental conditions, notably the intensity and quality of solar radiation intercepted by the canopy, are important drivers of soybean output and yield. It was concluded that grain yield was significantly influenced by maize soybean intercropping planting geometries and canopy manipulation of maize. The results may be attributed to improved light interception and enhanced growth resulting from maize leaf removal and detasseling, which has a good effect on soybean grain output. More sunlight and improved photosynthesis contribute to increased biomass production which can translate into higher grain yield. Wide row spacing had better yield of intercrops as compared with narrow row spacing (Wang et al., 2015). Different row patterns can improve light interception in the lower crop canopy (Addo-Quaye et al., 2011; Khan et al., 2019).

Biological yield determines the growth and development during the life span of the crop. It contributes directly to the plant yield through the production and allocation of photosynthates. Crops which have maximum biomass convert maximum assimilate for seed yield. The difference in biological yield was driven by the competitive environment between crop plants and the suppressive effect of maize on soybeans. Soybean is very sensitive plant in the sense of light as results of research showed less biological yield in intercropping treatments because soybean had to face so much competition due to dominance of maize plants. The results were comparable to those of Olewe, (2014) and Saba et al. (2017) who stated that soybean genotypes had significant variation in biological yield.

The leaf area index (LAI) is a significant factor regulating radiation interception, canopy photosynthesis, and yield. The increase in LAI reflects the general crop trends that rising plant density raises the leaf area index because greater area is occupied by the green canopy of plants per unit area. Highest values during both the years (Autumn 2020-21 and Autumn 2021-22) of LAI were recorded in treatment PG3CM4 where 75

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cm apart double row ridge plantation of maize with 2 leaf removal with detessaling) was followed. However, lowest values of LAI were reported with treatment PG2CM1 where 75 cm apart single row ridge plantation of maize with no leaf removal and detessaling was followed. The considerable variation between soybean leaf area index and planting geometries and Canopy modifications may be attributed to reduced solar radiation absorbed by the soybean due to shading from the maize plant. Raza et al., (2019) resulted that different planting geometries affect the leaf area index of soybean in maize soybean intercropping.

Higher crop growth rate (CGR) at different planting geometries and canopy manipulation techniques in maize soybean intercropping was due to higher dry matter buildup per unit area/time. Data pertaining to CGR recorded at fortnight intervals under different treatments for both years demonstrated that over time, it attained its highest value, demonstrating significant diversity across different treatments, and then fell until crop harvest. The similar results were also found by Limpinuntana et al. (2010). Limpinuntana et al. (2010) found that throughout the early period, particularly after 30 DAS, the CGR rises dramatically until 75 DAS, and then it gradually drops.

CONCLUSION

It is concluded from the two years' experimentation that in maize soybean intercropping, 75 cm double row ridge plantation promotes yield and productivity of soybean with 2 leaves removal and detessaling of maize.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

AUTHORS CONTRIBUTIONS

Anjum Naeem and Nasr Ullah Khan conceived the idea and designed the study. Anjum Naeem and Haroon Zaman Khan conducted the experiments, collected and analysed the data. Musadiq Manzoor, Shahana Aziz, Sana Akbar, Nida Afaqi and Hafiz Abdul Basit assisted the data collection and analysis steps. Anjum Naeem and Nasr Ullah Khan drafted the manuscript. All authors reviewed the manuscript before submission.

REFERENCES

- Addo-Quaye, A.A., A.A. Darkwa and G.K. Ocloo. 2011. Yield and productivity of component crops in a maize-soybean inter-cropping system as affected by time of planting and spatial arrangement. *ARPN. J. of Agric. Biol. Sci.* 6: 50-57.
- Ahmad, A., M.A. Wahid, M.W. Fazal, M.U. Anees, M.A. Arshad and M.T. Saeed. 2016. Agro-Economic Assessment of Maize-Soybean Intercropping System. *Am.-Eurasian J. Agric. Environ. Sci.* 16:1719-1725.
- Aziz, A., M. Abou-Elela, Usama, A. Abd El-Razek and H.E. Khalil. 2012. Yield and its

Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

- components of maize/soybean intercropping systems as affected by planting time and distribution. *Aust. J. Basic Appl. Sci.* 6: 238-245.
- Banik, P., A. Midya, B.K. Sarkar, and S.S. Ghose. 2006. Wheat and chickpea intercropping systems in an additive series experiment: advantages and weed smothering. *European Journal of agronomy*, 24(4), 325-332.
- Ehsanullah, M. Javed, R. Ahmad and A. Tariq. 2011. Bio-economic assessment of maizemash intercropping system. *Crop Environ.* 2:41-46.
- Karam D., I.A. PereiraFilho, P.C. Magalhaes, M.C.D. Paes, J.A.A. Silva, J.D.C.M. Gama. 2010. Resposta de plantas de milho a`simulacãõ de danos mecânicos. *Revista Brasileira de Milho e Sorgo* 9:201–211.
- Kefu, Z. 1981. Effect of the leaves of different positions in maize on the corn yield and the photosynthetic properties of those leaves after the growing out of the female flowers. *Acta Agrono Sin* 4:005.
- Khan, H.Z., M. Abdullah, M. Abrar, M.A. Shabbir, N. Akbar, A. Iqbal, M.F. Saleem and M.M. Farhain. 2019. Evaluating rherolw of maize-soybean intercropping in sustainable maize production. *J. Agric. basic Sci.*19:200-210.
- Khan, M.A., K. Ali, Z. Hussain and R.A. Afridi. 2012. Impact of maize-legume intercropping on weeds and maize crop. *J. Weed. Sci. Res.* 18:345-356.
- Liu, W.G., J.L. Zou, J. Zhang, F. Yang, Y. Wan and W.Y. Yang. 2015. Evaluation of soybean (*Glycine max* L.) stem vining in maize- soybean relay strip intercropping system. *Plant Prod. Sci.* 18:69-75.
- Luiz, B.M. and W.W. Robert. 2003. Effects of plant population and nitrogen fertilizer on yield and efficiency of maize-bean intercropping. *Pesq. Agropec. Bras.* Brasília. 38:1257-1264.
- Muneer, M., M. Saeed and M. Imran. 2004. Crop productivity and net returns in wheat-gram intercropping. *Pak. J. Agric. Res.* 18: 20-24.
- Olewe, V.I., C. Adejuyigbe, F. Osundiya, O. Ajibade, O. Adeboye, J.B akare. 2014. Agronomic performance of soybean (*Glycine max* L.) in an organic crop rotation system. Rahmann G & Aksoy U (Eds.) *Proceedings of the 4th ISOFAR Scientific Conference*.
- Raza, M.A. 2019. Optimum leaf defoliation: a new agronomic approach for increasing nutrient uptake and land equivalent ratio of maize soybean relay intercropping system. *Field Crops Res* 244:107647.
- Raza, M.A. B. Asghar, C. Ahmad, H.I. Bin, Hussain, W. Li and L. Weiguo. 2020. Agro-Techniques for Lodging Stress Management in Maize-Soybean Intercropping System—A Review. *Plants*, 9(11), 1592.
- Raza, M.A., M.H.B. Khalid, X. Zhang, L.Y. Feng, I. Khan, M.J. Hassan, M. Ahmed, M. Ansar, Y.K. Chen and Y.F. Fan. 2018. Effect of planting patterns on yield, nutrient accumulation and distribution in maize and soybean under relay intercropping systems. *Sci. Rep.* 9:4947-4957.
- Saba, I., P.A. Sofi, N.A. Zeerak, M.A. Bhat and R.R. Mir. 2016. Characterisation of a core set of common bean (*Phaseolus vulgaris* L.) germplasm for seed quality traits. *SABRAO J. breed. genet.* 48:359-376.
- 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

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- Intercropping. *Agron.* 10:110.
- Wu, Y., W. Gong, W. Yang .2017. Shade inhibits leaf size by controlling cell proliferation and enlargement in soybean. *Sci Rep* 7:9259. <https://doi.org/10.1038/s41598-017-10026-5>.
- Yang, F., et al 2017 Effect of aboveground and belowground interactions on the intercrop yields in maize–soybean relay intercropping systems. *Field Crops Res* 203:16–23. <https://doi.org/10.1016/j.fcr.2016.12.007>.
- Yang, F., X. Wang, D. Liao, F. Lu, R. Gao, W. Liu, T. Yong, X. Wu, J. Du, J. Liu and W. Yang. 2015. Yield response to different planting geometries in maize-soybean relay strip intercropping systems. *Agron. J.* 107:296-304.
- Yang, F., S. Huang, R.W. Wang, X. Wu and W. Yang. 2014. Growth of soybean seedlings in relay strip intercropping systems in relation to light quantity and red: far-red ratio. *Field Crops Res.* 155:245-253.